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NOTES FROM THE BIOLOGICAL LABORATORY.

Edited by Professor WILLIAM KEITH BROOKS.

Observations on the Gametophyte and Embryo of Taxodium Distichum, Richard. By W. C. Coker.

The material from which most of my results were obtained was collected at frequent intervals from Baltimore, Maryland, and Hartsville, South Carolina. Perfect seed are rarely found in Baltimore, and all stages after May 10th, are taken from South Carolina material.

In the early part of the year before their maturity both male and female flowers are easily distinguishable, the male flower being, however, considerably more developed on the 1st of October than the female. At this time the pollen sacks are large and, archesporium and tapetum are easily distinguishable. In the female flower the nucellus may be seen as a slight protuberence directly in the axis of the sporophyl, while the integument and placental cushion only appear later. Before the middle of March the integument has reached the tip of the nucellus and a group of cells situated at the base of the latter may be distinguished as primary archesporium. When the pollen is shed a week or two later the integument is about twice as long as the nucellus and the channel of the micropile opens freely by a wide mouth. The placenta now appears as a considerable prominence just above the ovule, being most developed in the central region of the sporophyl. The micropile now begins to close by the elongation of the inner cells of the integument near its tip and by the increase in the number of cells at this point. By May 10th the archesporium has reached its full size and is surrounded by several layered tapetum, which is, however, not closely demarked from it. The archesporium lies at the very base of the nucellus and in form and position is very like that of Juniperus, Callitris and other Cupressineae. One of the cells at or near the center of the group begins to enlarge and the other cells of the archesporium become loosened and show signs of disintegration, Whether there is a division of a mother cell into four macrospores has not been determined.

About the first of June the macrospore has reached its full size and extends nearly the whole length of the much-enlarged nucellus. The nuclei are still confined to a thin peripheral layer in the sac, but their increase is rapid and a cellular endosperm soon begins to form, its growth being most rapid at the micropilar end. After the endosperm has become a compact tissue, the nuclei, which are small in comparison to the cell cavity, begin to divide, apparently amitotically, and the cells become multinucleated, as many as 6 or 7 nuclei being not infrequent in one cavity. Meanwhile the tip of the integument has become much hardened by the development of thick, pitted walls in the cells of that region.

By June 6th, the mother cells of the archegonia have become greatly elongated and the neck cells are being cut off. The archegonia are situated in close contact in a group at the tip of the prothallus and soon come to lie in a deep depression just as in the Cupressineae. After fertilization this depression is closed by the growing in of the nucellus over the archegonia. The neck cell divides into four as in Juniperus. Just before fertilization, which occurs about a week later, a ventral canal cell is cut off and lies as a mass of nuclear matter just under the neck cells and usually near the wall of the archegonium. The female pro-nucleus remains near the tip of the oosphere and is in this position at the time of fertilization. The mature oosphere contains two masses, one at each end, which stain like the other cytoplasmic contents, but, by their greater density and distinct limits, are very conspicuous.

The lower ends of all the archegonia and the outer edges of the peripheral ones are bordered by a distinct layer of densely granular cells, which doubtless helps to nourish the oosphere, as in these regions the wall between the two is furnished with large pits These pits have not been carefully studied, but seem to resemble those of the Abietinease, Taxaceae and Cycadeae in function.

The pollen sprouts almost immediately on reaching the nucellus, and the tube grows with little or no interruption until it touches the still nearly empty embryo-sac about the 1st of June. The early stages of sprouting have not been observed, but by May 10th the tube has reached about half way to the embryo-sac and contains three nuclei near its growing point. These are probably the pollen tube nucleus, the stalk nucleus, and the body cell nucleus. When the pollen tube has reached the embryo-sac, the three nuclei are seen in a group. The body-cell nucleus is somewhat larger than the other two, and lies just behind them. As many as three or four tubes may push their way into the funnel over the archegonia, as may also happen in Juniperus and Thuja. The body nucleus increases rapidly in size and becomes surrounded with a mass of dense protoplasm, which, before division, is separated from the other protoplasm of the tube by a sharp and distinct surface. Just before fertilization the male nuclei divide into two as in other cases. All the nuclei in the pollen tube pass into the archegonia in fertilization, but the tube and stalk nuclei are undergoing disintegration at the time and can not be certainly located in the oosphere; but, in connection with the broken-down neck cells, form a more or less evident granular mass in the tips of the archegonia after the the collapse of the tube. Both male pro-nuclei may enter into the same archegonium, in which case one remains at the tip and is evident even after several divisions of the oospore. The male and female pronuclei come in contact near the upper end of the archegonia, and are partly surrounded at this stage by a dense mass of cytoplasm the origin of which is at present obscure. The nuclei travel together towards the base of the oospore and the cytoplasmic mass gradually draws itself entirely around them. They do not fuse completely until the bottom is nearly or quite reached.

The first division of the oospore does not seem to be constant in direction, the wall formed being either perpendicular to the long axis of the archegonium or more or less inclined to it. In the next stage obtained, the pro-embryo consists of three tiers of four cells each. In the upper tier no cell walls are found, or if so they are soon dissolved, so that the nuclei lie free in the cavity of the archegonium. The pro-embryo in this stage is very like that of Juniperus, as it is also a little later, when the number of tiers has increased to four and the second tier from the top has greatly elongated so that the embryo is forced out into the endosperm.

The results so far arrived at point to the conclusion that in the stages of its development described above Taxodium agrees closely with the Cupressineae, and differs widely from Sequoia as described by Shaw.

PLANTS, A TEXT-BOOK OF BOTANY.[1]

A Review by D. S. Johnson.

The conception and plan of Part I of the book were evidently guided by the desire to illuminate the facts of plant structure by the results of modern ecology.

Of the pre-eminent suitability and interest of these facts for beginners and for those who never go far beyond this stage there can be little doubt, for, as the author suggests, these are the phenomena which are open to observation everywhere without apparatus or artificial experimentation. Neither can it come amiss for those who expect to pursue the subject further to become thoroughly impressed at the start with the fact, which is easily lost sight of in reading many text-books of botany, that the important thing is not structure as such but structures as efficient tools or organs for carrying on the work of the plant.

Of the several recent attempts to present in a form suitable for beginners the primary facts of this relation of structure to function, and thus to environment, the present seems to the reviewer to be the most satisfactory. The difficulty hitherto experienced has been that of attaining a clear logical arrangement, with a *raison d'être* which shall be to some extent at least evident to the student, an advantage that, whatever its other shortcomings, has been possessed by the formal structural botany of the past.

As to the exact order in which the various topics should be taken up there is much difference of opinion, but the naturalness with which each topic here leads the student on to the next is sufficient evidence that the author's way is at least *one* of the good ones.

In the second half of the book we find a brief but clear presentation of the life histories of the chief groups of plants and short chapters on histology, physiology and ecology.

It is very gratifying to find the author using the term "vegetative multiplication," for those modes of forming new individuals where (usually) slightly modified vegetative parts are concerned, instead of confusing the primarily distinct adjectives "vegetative" and "reproductive" as has been frequently done of late by combining them into one word to describe the above mentioned process. It is doubtful also whether the substitution (on p. 110, Part I) of "egg" for fertilized egg or oospore is a wise one, since this incurs the risk of causing confusion later on when the proper term is used for the same thing.

In speaking of secondary growth (on p. 288, Part II) a few words might have suggested the origin of secondary pith rays, which must, as the discussion stands, prove troublesome puzzles to the reader who seeks here an explanation of the structure of common woody stems.

The choice of a liverwort which will show the essential features of development in this group and at the same time be generally obtainable is perhaps difficult, but it is certainly true that making Marchantia the principal type introduces exceptionally complicated structures, at a point where the essential new features are sufficiently difficult to grasp. Moreover, it is apt to become the typical liverwort in the student's mind and so to partially obscure the close resemblance of the life-history here to that of the mosses. The reviewer believes that the substitution of some species of the common genera Pallavicinia, Pellia or the foliose Scapania, Lophocolea, etc., would best serve the end in view in a brief study of the group.

Finally in the illustration of the book both author and printer have been highly successful. The figures of toadstools copied from Gibson are sufficient evidence that the artistic quality may be a decided addition to a scientific drawing when combined with a proper degree of accuracy, while in the many original drawings that replace certain standard figures it is pleasing to find other merits than mere newness to warrant the substitution.

On the Embryo-sac of Saururus Cernuus. By Duncan S. Johnson.

The development of Saururus has been studied during the past winter in connection with work on the Piperaceae. The material used was obtained chiefly at Beaufort, N. C., while the writer was at the U. S. F. C. laboratory there during the summer of 1899. The points especially studied are the development of the flower and fruit and the sprouting of the seed. The flower, which consists of four carpels and six stamens on the upper surface of a spoon-shaped bract, develops in a manner like that described by Schmitz for the Piperaceae. The ovules are two in each carpel of which but one matures to a seed.

The primary mother cell of the embryo-sac is hypodermal and forms a single tapetal cell above. It then divides to three potential macrospores of which the lower becomes functional. The nucleus of this divides to eight in the usual way and from these are formed the typical egg apparatus, endosperm nucleus and three evanescent antipodals.

After fertilization the egg remains quiescent for some time and the synergids persist indefinitely. After the first division of the endosperm nucellus one of the daughter nuclei remains in the upper end of the now flask-like embryo-sac, while the other moves down into the body of the flask and a wall is formed across the lower end of the neck separating the cavity of the embryo-sac into two. The lower nucleus becomes very large and apparently controls the, at first rapid, encroachment of the basal portion of the embryo-sac upon the tissue of the nucellus, but never divides further and degenerates before the seed is ripe.

The upper nucleus continues to divide and forms a cell wall immediately after each division. In this way the neck of the embryo-sac is soon filled and then by lateral growth the endosperm swells out to fill the whole upper pointed end of the seed, like a double cone, with the lower end reaching down one-fourth of the length of the seed to the body of the flask-like embryo-sac cavity, which body is filled only with a lightly staining apparently slimy substance. All the other space within the seed coats is filled by the densely stored tissue of the perisperm. The embryo begins to develop before the endosperm has widened much. The first division is transverse and when the seed is ripe the embryo has just begun to show a heart-shaped form, with the very short suspensor and blunt root above and the cotyledons showing as two very short lobes below, the whole being surrounded then by six or more layers of endorsperm on all sides and below.

In this condition the seed rests, surrounded by the spongy carpel and outer integument and a principal seed coat formed by the much thickened outer layer of the inner integument.

At sprouting the endosperm bursts through at the tip of the seed as a whitish papilla, within which is a cavity containing the embryo. The latter soon pushes its root out at the tip of the endosperm papilla and bends down to the soil. The tips of the oval cotyledons are tightly clasped by the endosperm and remain attached while the whole fruit is raised from the ground.

The endosperm expands within to absorb all of the perisperm and the swollen tips of the cotyledons crowd the thin endosperm out against the food supply.

In conclusion then the structure of the flower and of the sporophyte in general indicates relationship with the Piperaceae. The embryo-sac is typical while the mode of formation of the endosperm and the small amount of it in the ripe seed is found also in such an evidently distantly related family as the Nymphaeaceae.

The behavior of the endosperm at sprouting is unusual, but we may regard it as completing during sprouting, the function of breaking down the nucellus for the use of the embryo, which in such seeds as those of Phaseolus, Pisum, etc., is completed before the seed ripens.

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[1] *Plants, A Text-book of Botany.* By John M. Coulter, A. M., Ph. D. Head of the department of Botany of the University of Chicago. New York, D. Appleton & Co., 1900. Part I, Plant Relations, pp. 264; Part II, Plant Structures, pp. 348.

The Embryo-sac of Peperomia Pellucida. By Duncan S. Johnson.

The material of various Piperaceae collected in Jamaica in 1897 by the late Prof. Humphrey included an abundance of well preserved material of the above species. The following abstract gives the most important results from the study of this material.

The development of the flower is essentially as described by Schmitz. The flower consists of a top-shaped bract in the axil of which is borne a single carpel with a single stamen on each side. The single orthotropous ovule has but one integument and closely fills the cavity of the ovary.

The primary archesporial cell is single and subepidermal. It cuts off a single tapetal cell above and then immediately develops to the embryo-sac. The nucleus of the embryo-sac divides by mitosis to sixteen similar nuclei, distributed about in the peripheral layer of cytoplasm. Two of these nuclei are soon found at the upper end of the sac with a rather larger portion of cytoplasm about each. The larger of these two nuclei with its cytoplasm forms the egg, the wall of which is at first very delicate and indistinct. The other seems to play the part of a synergid and it likewise has no distinct wall until a much later stage.

At about the time the pollen tube reaches the egg eight of the remaining fourteen peripheral nuclei collect in a compact group, located near the lateral or basal wall of the embryo-sac or central and often just below the egg. Before the male and female nuclei fuse these eight nuclei fuse together completely into one large nucleus which from this time behaves like the endosperm nucleus of the ordinary Angiosperm embryo-sac.

This nucleus begins to divide before any change is visible in the egg. The first spindle formed by the endosperm nucleus is transverse and the cell wall which immediately forms from the spindle fibres stretches from the now well defined wall of the fertilized egg to the base of the still spherical embryo-sac. The two endosperm cells thus formed divide further as development goes on still in the latest stages seen, probably nearly ripe seeds, there are fifteen or twenty endosperm cells forming a single layer around the embryo except above it. The latter at this time consists of fifteen or more cells reaching down nearly half way to the base of the embryo-sac, The single synergid persists even to this stage and remains distinct from both the embryo and endosperm.

The remaining six peripheral nuclei are seen at this stage to be flattened against the wall of the but little enlarged embryo-sac by the endosperm cells and show signs of degeneration.

The endosperm cells appear at this time to have protoplasmic contents only, but the whole tissue of the relatively much enlarged nucellus is densely packed with starch.

The results here given agree with those recently published by Campbell, for this form up to the sixteen nucleate stage of the embryo-sac. But he finds two synergidae and interprets the group of eight nuclei as probably antipodals, which he thinks separate again later. He also interpreted as part of the embryo the mass of endosperm cells which finally fill most of the embryo-sac and therefore concludes that there is no endosperm.

The author hopes in the near future to be able to study the sprouting of the seed in this plant and thus to discover whether the part played by this supposed endosperm at that time is such as to demonstrate this as its true homology.

Order of Appearance of the Mesenteries and Septa in the Madreporaria. By J. E. Duerden.

Within the Madreporaria the number and arrangement of the septa should be the most fundamental characteristic, as is the case with the mesenteries among the Actiniaria. Often, however, so many variations and seeming irregularities occur, even in forms which are otherwise closely related, that their value for taxonomic purposes has been much impaired. This has been all the more forcibly impressed since it has been demonstrated in several instances that the adult arrangement may be of a type different from that in the early stages. The tendency to diminish the importance of the septal plan has reached its climax in the attempt of Quelch and others to distribute the old group Rugosa or Tetracoralla among the more modern hexamerous families.

The true significance of the septal arrangement of corals, and often the actual arrangement itself, can only be determined by full investigations of the soft parts of the polyps at different stages. It was the hope of furthering this, and, if possible, of discovering some indications of relationships from the polyps themselves, that induced workers like Prof. G. von Koch, Dr. G. H. Fowler, and Prof. G. C. Bourne to undertake their elaborate investigations on the morphology of Madreporarian polyps. So far, the results from this standpoint are confessedly disappointing. They have in the main but served to demonstrate the general Hexactinian character of the group. Of late years von Koch, Ortmann, Miss Ogilvie, and others have directed their attention to the microscopic structure of the corallum, and have sought to obtain from this characters of classificatory value.

A residence within the neighbourhood of coral-reefs has afforded me the opportunity of examining, both in the living condition and anatomically, over a score of species of coral polyps, all well known, West Indian shallow water forms. The following notes are a brief résumé of what appear to be the more important results in connection with the order of appearance of the mesenteries and septa.

The first six pairs of mesenteries are found to differ so essentially in their mode of origin and significance from the mesenteries appearing later that I find it convenient to have some word which will include them either as a whole or individually. I therefore propose for them the term "Protocnemes," and shall refer to the mesenteries subsequently developed as "Metacnemes." Similarly with the septa: the six or twelve primary septa, appearing in association with the protocnemes, will be referred to as "Protosepta," and the later formed members as "Metasepta."

Development of the Protocnemes.

From the time of the publication of the classic researches of Prof. H. de Lacaze-Duthiers (1872–73) onwards, numerous embryological studies, upon both the Actiniaria and Madreporaria, have demonstrated that the twelve primary mesenteries always arise in bilateral pairs in a definite order.

In the larvae of *Actinia mesembryantheum*, *Bunodes gemmacea*, etc., Lacaze-Duthiers found that the first pair of mesenteries divided the coelenteric cavity into two unequal compartments. The second pair appeared in the larger or dorsal of the two chambers, cutting off a middle chamber; then within the primary smaller or ventral chamber the third pair was developed. The fourth pair is described as appearing between the first and second pairs, but most subsequent researches have demonstrated that it arises at the dorsal extremity, its members becoming the sulcular directives. The fifth and sixth pairs arise practically simultaneously, and, as now proved for a number of forms, within the middle and sulco-lateral chambers on each side. The relative positions of the second and fourth pairs of mesenteries, as understood by Lacaze-Duthiers, are represented on the annexed figure by the Arabic numerals, while the Roman numerals show the order since established (Fig. 1). In his last important contribution on corals Prof. Lacaze-Duthiers (1897) indicates that in *Balanophyllia regia* the fourth pair of mesenteries is situated between the first and third pairs, that is, it corresponds with the sixth pair of Fig. 1.

The order of appearance of the primary mesenteries in such that each new pair arises within the succeeding oldest and largest chamber, which thereby becomes divided into two compartments on each side.

Two of the most complete series of stages in the development of the protocnemes of Madreporarian polyps are now known, as a result of the researches of Prof. H. V. Wilson and Prof. G. von Koch. H. V. Wilson (1888) has traced their origin in the West-Indian coral, *Manicina areolata*, from the earliest stage in the larva to the young polyp with three cycles of mesenteries. The second and fourth pairs of protocnemic mesenteries being transposed, Wilson's results agree with those of Lacaze-Duthiers. G. von Koch (1897) describes and figures the order of development in the young polyp of *Caryophyllia cyathus*, from the stage with four mesenteries to the completion of the first cycle. In this species the sequence is in perfect agreement with that obtained by Wilson.

My own results upon the larvae of *Manicina areolata* confirm those of Wilson. Stages with from three to six pairs of mesenteries have been obtained, the last (Fig. 1) also reproducing most of the details of von Koch's figure (p. 670) of Caryophyllia. The young polyps of Manicina remained for a week or two at the protocnemic stage, the first cycle of septa arising in the meantime. Evidence confirmatory of the same order of sequence has also been obtained from the larvae of *Favia ananas* and *Cladocora arbuscula*; stages with from three to six pairs of mesenteries have been secured. Non-extruded larvae of *Porites clavaria* also reveal a phase with only three pairs of mesenteries, and the adult polyps complete the stage shown in Fig. I.

The examination of a number of early stages in the budding of polyps discloses that in the asexual method of increase there is the closest agreement in the order of development of the mesenteries with that above described for the sexually-produced polyps. The youngest bud obtained is from a colony of *Cladocora arbuscula*; only eight protocnemes are present, all united with the stomodaeum. Shortly below the stomodaeum only four mesenteries remain, and bear mesenterial filaments; then two of these disappear; and the two remaining, representing the first pair to arise, are continued much further, and bear filaments almost to their termination. In other buds of Cladocora sectionized all the protocnemes are already developed; the Edwardsian mesenteries are complete, and the fifth and sixth pairs incomplete, just as in the larva of Manicina (Fig. 1).

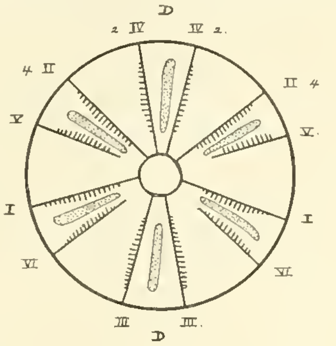

Fig. 1.

Diagrammatic arrangement of the mesenteries of a young polyp of *Manicina areolata* at the stage with six entocoelic septa. Only six pairs of Protocnemes are present, the Edwardsian mesenteries complete, and the fifth and sixth bilateral pairs incomplete. The Roman numerals indicate the order in which the pairs of mesenteries have been found to appear, while as regards the second and fourth pairs the Arabic numerals give the order as understood by Prof. Lacaze-Duthiers. Mesenteries VI. and I., and V. and II. on each side of the polyp constitute 'unilateral' pairs, in contradistinction to the 'bilateral' pairs in which the moietes are on the opposite sides. The same stage of mesenterial development occurs in most of the mature polyps of Madrepora and Porites, and is a resting stage in the development of many coral and Actinian larvae and of asexually produced coral buds. The lower aspect is ventral or sulcar, the upper dorsal or sulcular. D, D, Directives.

Similarly with buds of Solenastraea: stages have been obtained in which only four pairs of mesenteries are complete and bear mesenterial filaments, while the two incomplete pairs are devoid of filaments and disappear in advance of the others. In a very early bud of Madrepora sectionized all the protocnemes are already present, but their relative size and extent of course are such as to suggest that the pairs appeared in the order established for the mesenteries of sexually originating polyps.

The polyps of the three types of West-Indian Madrepora (*palmata*, *prolifera*, *cervicornis*), as also those of three different species of Porites examined, rarely develop beyond the protocnemic stage. The four pairs of Edwardsian mesenteries are nearly always complete, and the fifth and sixth pairs are incomplete throughout the extent of the stomodaeum, and devoid of mesenterial filaments. The adult polyps of Madrepora and Porites then are essentially larval as regards the extent of development of the mesenteries, and in the fuller account it will be shown that the tentacles are in a similar phase.

Summarizing we find:

(1). That the twelve protocnemes arise within the larva in bilateral pairs in a definite order, which is probably the same throughout the Madreporaria and Actiniaria.

(2). Two pairs of directives are always present.

(3). The first four pairs are the earliest to unite with the stomodaeum (Edwardsia-stage), and a long interval may elapse before the fifth and sixth pairs become complete, and the metacnemes appear.

(4). The development of the protocnemes in asexually-produced buds is in close agreement with that of sexually-produced polyps.

(5). Most of the polyps of the genera Madrepora and Porites never pass beyond the protocnemic stage.

ORDER OF DEVELOPMENT OF THE METACNEMES.

While much attention has been given to the order of appearance of the protocnemes in the Madreporaria and Actiniaria, comparatively few observations have been recorded with regard to the sequence of development of the metacnemes. For the Madreporaria the establishment of this becomes a matter of great importance, seeing that by it is determined the septal arrangement of the adult coral.

The passage from the protocnemic to the metacnemic stage of Actinozoan development is one of the greatest morphological significance. Prof. Lacaze-Duthiers was the first to realize this in the Actiniae. Thus, in his résumé of the development of *Actinia mesembryanthemum*, etc., (p. 362) he writes: "Ainsi la loi qui préside à la multiplication des parties depuis l'origine jusqu'au nombre douze, n'est pas la même que celle qui régit la multiplication après que ce chiffre est atteint."

As regards sexually-produced coral polyps we have no records of the actual order of appearance followed by the metacnemes. The embryological observations of Lacaze-Duthiers, von Koch, and Wilson, so far as they concern the polyps themselves, practically cease with the protocnemic stage. From a study of young buds I have, however, obtained a number of such developmental stages, and there is little doubt that the sequence in these is exactly the same as that in polyps with direct larval predecessors. Buds and young polyps of *Cladocora arbuscula* will serve as examples up to a certain stage.

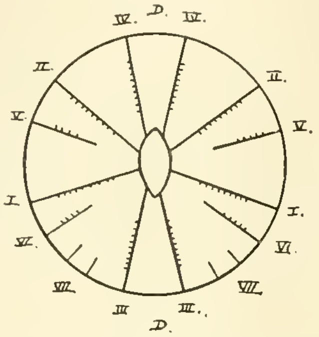

Fig. 2.

Plan of mesenterial arrangement in a young bud of *Cladocora arbuscula*. The protocnemes are at the same stage of development as in Fig. 1, but two pairs of metacnemes (VII., VII.) have appeared within the ventral exocoeles.

Fig. 2 represents diagrammatically a transverse section through a bud in which two pairs of mesenteries are present, in addition to the twelve protocnemes; of the latter, only the Edwardsian mesenteries are complete, and bear mesenterial filaments below. The two pairs of metacnemes occur in the exocoeles, one on each side of the sulcar or ventral directives, and as yet are very rudimentary, extending but a short distance down the column-wall. No muscular elements nor mesenterial filaments are distinguishable.

A transverse section through a somewhat older bud of Cladocora is represented in Fig. 3. Even yet the fifth and sixth bilateral pairs of protocnemes are free towards the lower termination of the stomodaeum. Six alternating pairs of metacnemes are now present, but show a marked gradation, in the extent of their development, in passing from the ventral to the dorsal aspect of the polyp. Mesenterial filaments occur on the pairs in the ventral exocoeles, and the longitudinal muscle fibres are recognizable; muscle fibres are also present on the pairs in the middle lateral

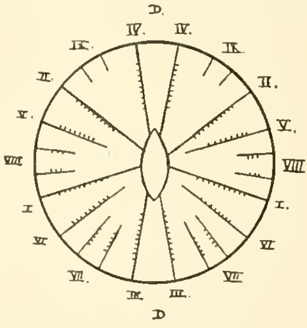

Fig. 3.

Plan of mesenterial arrangement in an older bud of Cladocora. Six pairs of metacnemes (VII.-IX.) have appeared, and show a progressive development from the ventral to the dorsal aspect.

exocoeles, but no trace of mesenterial filaments; the pairs in the dorsal exocoeles are very rudimentary. The proportional development indicates, as does also the previous figure, that the sequence of appearance of the metacnemes is from the ventral to the dorsal border of the polyp, which in regard to the colony as a whole is from the abaxial to the axial aspect. At a little later stage the mesenteries are arranged as follows: (1) six protocnemic pairs, all the members complete and forming unilateral pairs, except the directives, which remain bilateral pairs; (2) six alternating metacnemic pairs, all incomplete, equally developed, and bearing filaments. Many polyps in a colony are not developed beyond this stage.

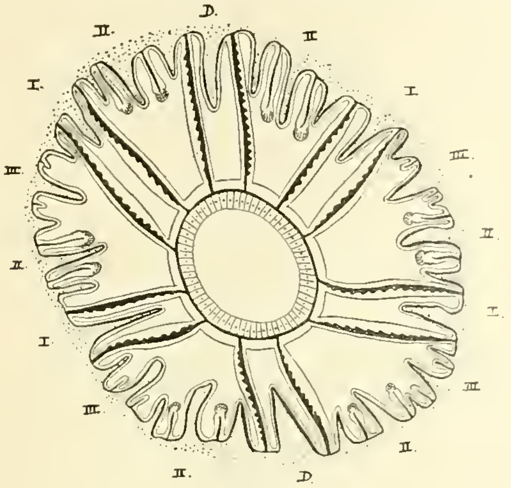

FIG. 4.

Transverse section through a polyp of Cladocora with sixteen pairs of mesenteries and corresponding entocoelic and exocoelic septal invaginations. The four pairs of second-cycle metacnemes (III., III.) are very small, and occur on the dorsal aspect of the ventral and middle first-cycle metacnemes.

We may now consider the order of appearance of the second-cycle metacnemes. These, when complete, consist of twelve pairs disposed within the twelve exocoeles of the first-cycle metacnemes and the protocnemes. Mature polyps of Cladocora usually possess a certain number of second-cycle metacnemes, but never the full complement. Fig. 4 represents a transverse section through the stomodaeal region of a polyp with sixteen pairs of mesenteries. Of these the six complete pairs are protocnemes, the six alternating pairs are first-cycle metacnemes, and the four pairs remaining are the only representatives of the second-cycle metacnemes. The latter are but feebly developed and devoid of mesenterial filaments.

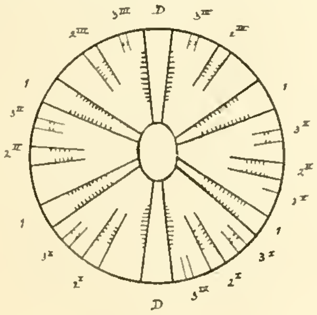

FIG. 5.

Plan of mesenterial arrangement in a young polyp of *Manicina areolata*. Six pairs of second-cycle metacnemes (3I.–3III.) have appeared in the dorsal exocoele of each primary system, and the six remaining pairs are now beginning to arise in the ventral exocoele of each primary system (3IV., 3V.).

The fact of greatest importance in connection with the new pairs of metacnemes is their restriction to the exocoeles on the dorsal aspect of the first-cycle metacnemes, not to both the dorsal and ventral aspects as considerations of symmetry would suggest. The latter consideration is evidently overcome by spatial necessities.

The polyps of *Cladocora arbuscula* very rarely pass beyond the stage with sixteen mesenteries, which corresponds externally with thirty-two tentacles. For the further mesenterial sequence, therefore, other species will be employed. Fig. 5 is a diagrammatic representation of the mesenteries in a young polyp of *Manicina areolata*, as they appear in sections towards the lower termination of the stomodaeum. Six complete pairs of protocnemes are present, six well developed, incomplete pairs of first-cycle metacnemes, and six small pairs of second-cycle metacnemes. The last series are disposed in the same relative positions as in Cladocora. The lower portion of the figure reveals how the remaining six pairs of second-cycle metacnemes, necessary to complete the cycle, arise. One pair is seen on the right side, within the exocoele between the ventral pair of directives and the pair of first-cycle metacnemes. In the corresponding middle exocoele a single mesentery has also appeared, but none as yet on the left side.

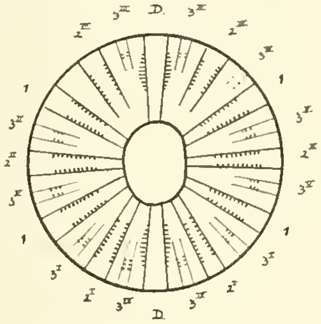

FIG. 6.

Plan of mesenterial arrangement in a polyp of *Phyllangia americana*. Ten pairs of mesenteries (six protocnemes and four first-cycle metacnemes) are united with the stomodaeum. The full complement of twelve pairs of second-cycle metacnemes is now present, except the two pairs in the ventral exocoeles of the two dorsal primary systems.

Polyps of *Phyllangia americana* afford some interesting stages beyond that represented by Manicina. In Fig. 6 four pairs of second-cycle metacnemes have become united with the stomodaeum, in addition to the protocnemes, but the dorsal pair on each side is yet incomplete. Ten pairs of second-cycle metacnemes are present, but the exocoele between the dorso-lateral pair of protocnemes and the most dorsal pair of first-cycle metacnemes is still unoccupied. On the right side, however, such a pair (3VI) is seen making its appearance in the sections somewhat higher.

Fig. 7 represents a slightly further stage of mesenterial development in the same species. Twelve pairs of mesenteries are now united with the stomodaeum; six pairs are the protocnemes, and the other six alternating with these are the first-cycle metacnemes. The full complement of twelve pairs of second-cycle metacnemes is also represented, and, at the lower aspect, a few pairs of third-cycle metacnemes have made their appearance. None of the species at my command goes beyond the stage represented by Phyllangia.

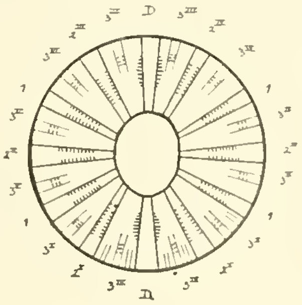

FIG. 7.

Mesenterial arrangement in another polyp of *Phyllangia americana*. The twelve pairs of second-cycle metacnemes are now completed and representatives of the third-cycle metacnemes are appearing at the ventral aspect.

Mesenterial sequences similar to the above have been obtained from buds and polyps of other corals, such as species of Solenastraea, Siderastraea, Orbicella, and Astrangia. There can be no doubt that the order thus briefly outlined is, in the main, that followed by corals in which the mesenteries are disposed in regular hexameral cycles. Certain exceptions have been met with, which must be regarded as characteristic of individual species; and irregularities at times creep in, especially in the later cycles. Thus in *Solenastraea excelsa* the metacnemes may arise first on the sulcular aspect of the polyp; in one young bud the two first pairs appeared in the middle exocoelic chamber on each side; further, the succession follows quite a different plan after the completion of the first cycle of metacnemes.

In all the genera mentioned asexual reproduction is by columnar budding, but in Manicina, Maeandrina, Colpophyllia, Isophyllia, Dichocoenia, etc., discal fission prevails. A successive series of preparations of *Manicina areolata* has been secured, as far as the stage with four oral apertures, so that the effect of discal fission upon the mesenterial arrangement can be traced. It is found that the cyclical plan, with two pairs of directives, prevails in the young, sexually-produced polyps, but tends to disappear after the first two or three stomodaeal systems have been established by fissiparity. In the most characteristic genera increasing by this means, only one or two orders of magnitude are represented by the mesenteries. Further, two pairs of directives are never found in polyps produced by fissiparity, while such appear to be always present in polyps arising by budding.

With regard to the metacnemes the results may be stated as follows:

(1). In most coral polyps the addition of mesenteries beyond the primary six pairs takes place in successive unilateral pairs; the corresponding pairs on each side are mostly simultaneous in their appearance, and are always exocoelic in position.

(2). The first cycle of metacnemes, consisting of six pairs, arises in successive pairs from one aspect of the polyp (sulcar or ventral) to the other (sulcular or dorsal), the pairs afterwards becoming equal. They usually remain free from the stomodaeum, but in large polyps may become connected in successive order.

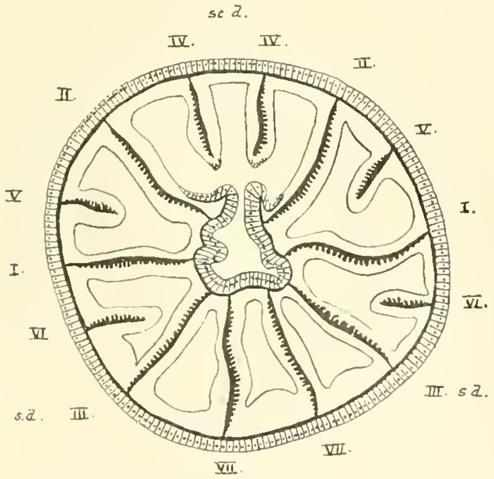

FIG. 8.

Transverse section through the lower stomodaeal region of a polyp of *Porites clavaria*. The stomodaeum is already terminated on the dorsal aspect, the sulcular directives (*sc. d.*) having become free. In addition to the six pairs of protocnemes (I.–VI.) another pair of mesenteries (VII.) has appeared within the entocoele of the ventral or sulcar pair of directives (*s. d.*, *s. d.*).

(3). The second-cycle metacnemes consist of twelve pairs; six pairs arise in succession from one aspect of the polyp to the other, and all on the same aspect of the first cycle metacnemes; the remaining six pairs appear in the same succession, but on the reverse aspect of the first-cycle metacnemes.

(4). In any species the adult polyps may or may not possess the full number of pairs necessary for the completion of the last cycle commenced.

(5). Polyps originating by discal fission lose, for the most part, the cyclical regularity characteristic of the sexually-produced polyps, and of polyps originating by columnar gemmation; directive mesenteries are also absent, though they always occur in the latter.

INCREASE OF MESENTERIES IN PORITES.

As already mentioned, the tentacles and mesenteries in the genus Porites are nearly always twelve in number, and larval in the extent of their development. Very exceptionally polyps are met with in which these organs may be increased to fourteen, sixteen, or even to twenty-four; similar increases are likewise found here and there in the septa of individual corallites. An examination of transverse sections of the larger polyps reveals that the increase in the number of mesenteries takes place in a manner different from any yet described in the Madreporaria. In Fig. 8 is represented a transverse section through the lower stomodaeal region of a polyp in which fourteen mesenteries are present, that is, two beyond the usual number. The primary mesenteries retain their original condition,—four pairs complete and two pairs incomplete. Within the sulcar or ventral entocoele, however, another complete pair (VII.) has been added, and the sulcar directives are pushed further apart. The retractor muscles on this newly added pair are on the faces of the mesenteries turned towards each other, so that each forms with the adjacent directive mesentery a unilateral pair, in which the retractor muscles are on the mesenterial faces turned away from one another, as in directives proper.

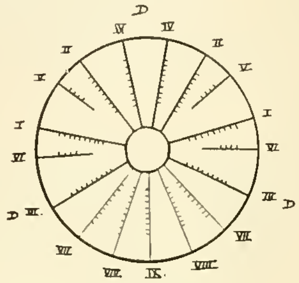

FIG. 9.

Plan of mesenterial arrangement in another polyp of Porites. Five complete mesenteries (VII.–IX.) now occur within the entocoele of the ventral directives (III., III.).

The next stage obtained is one in which fifteen mesenteries occur; fourteen are in the same condition as in the previous figure, and the additional member appears within the entocoele of the seventh pair. Fig. 9, from a polyp with seventeen mesenteries, shows how the increase is being carried out. Within the entocoele of the seventh pair another complete pair (VIII., VIII.) has been added. The longitudinal muscles are on the faces turned away from one another, so that now the members of the metacnemic pairs (VII., VIII.) on each side of the polyp form a unilateral pair, in which the musculature is on the faces turned towards each other. The odd mesentery (IX.) is again situated in the entocoele of the last formed pair.

In Fig. 10 is given the mesenterial arrangement of a polyp with ten pairs of mesenteries, as presented just below the stomodaeal region. The twelve dorsal mesenteries, represented by thicker lines, are the protocnemes, and the eight ventral mesenteries, indicated by thinner lines, are the metacnemes. The paired arrangement is constituted as follows: The pair, IV., IV. are the dorsal directives, and form a bilateral pair; II. and V., on each side, represent a pair of which one mesentery is larger than the other; similarly with I. and VI., on each side. Mesenteries III., III. are the ventral directives, and are now widely apart; each forms with VII. a mesenterial pair on each side, in which the musculature is on the faces turned away from one another, as in directives. Mesenteries VIII. and IX., on each

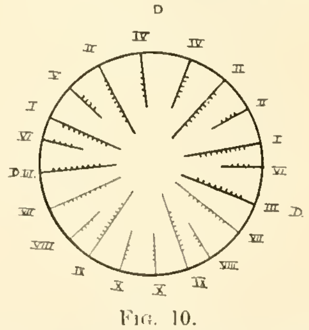

FIG. 10.

Plan of mesenterial arrangement a little below the stomodaeal region of a polyp of Porites with eight additional mesenteries The pairs are now constituted of a larger and a shorter mesentery, except in the case of the dorsal directives where both mesenteries are small, and of the pair III. and VII. on each side. Here both members are large and bear the longitudinal musculature on the faces turned away from one another.

side, form an unequal pair, in which the larger mesentery is on the ventral aspect, the reverse of that in pairs II., V., and I., VI. The pair X., X., is the last to appear, and is brachycnemic, with the musculature on the faces turned towards one another.

The next figure presents another arrangement. The new mesenteries are added at the sulcular or dorsal region of the polyp, not as in all the former, at the sulcar or ventral end. The six primary pairs still retain their original condition, but the sulcular directives (IV., IV.) are now widely separate, and enclose within their entocoeles three additional bilateral pairs of mesenteries. As in the previous case, the bilateral mesenteries, VIII. and IX., form two unilateral pairs, and each of the sulcular directives, along with the members of the seventh pair, also constitute two unilateral pairs, but with the musculature on opposite faces. The furthest stage obtained is one in which twenty-three mesenteries occur. Here also the new members arise within the sulcular entocoele. The bilateral pairs, VIII. and IX., and X. and XI., constitute four unilateral pairs.

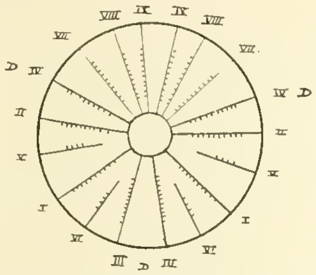

Fig. 11.

Mesenterial arrangement in a polyp of Porites in which three additional bilateral pairs of mesenteries (VII.–IX.) occur within the entocoele of the *dorsal* directives (D. IV.).

The new mesenteries are arranged throughout at practically equal distances apart, and extend downwards in the polyps to the same extent as most of the complete members of the primary series, and, like them, bear mesenterial filaments. All may be complete, but there is obviously a tendency to the formation of alternately large and small bilateral pairs, especially below the stomodaeal region, and the fifth and sixth protocnemic pairs remain incomplete.

The results may be thus summarized:

(1). In Porites the additions of mesenteries beyond the six primary pairs are always made at either the sulcar or sulcular region of the polyps, and within an axial entocoele.

(2). The new members arise in bilateral complete pairs, the latest formed appearing within the entocoele of the previously formed pair.

(3). The longitudinal muscles on the mesenteries are so arranged that the members of the first additional pair constitute, with the sulcar or sulcular directives, as the case may be, two unilateral pairs, in which the musculature is on the faces turned away from one another. In the succeeding pairs the musculature is alternately on the inner and outer faces, so that the eighth and ninth bilateral pairs on each side form a unilateral pair in which the muscular faces are turned towards each other, and likewise the tenth and eleventh pairs.

(4). Below the stomodaeum the unilateral pairs consist of alternately longer and shorter mesenteries, the order varying according as the additions are sulcar or sulcular in position.

The great distinction thus established between the manner of appearance of the metacnemes in Porites, and that in all other known coral polyps, is seen to be that, in the former, additions takes place in bilateral pairs at only one region, and within an entocoele, whereas, in the latter, the additions are made all round the polyp in unilateral pairs, and within exocoelic chambers; in the former the mesenteries remain unicyclic, in the latter they become multicyclic. In Porites the unilateral pairs below the stomodaeum consist of a brachycnemic and a macrocnemic moiety, while in other Madreporaria the members of a pair are alike in size throughout, and agree with the others belonging to the same cycle.

The three principal divisions of the Actiniaria—Hexactiniae, Zoantheae, Ceriantheae—are also characterized by a difference in the origin of the metacnemes. In the Hexactiniae they appear in unilateral pairs within the exocoeles of the primary cycle, and ultimately give rise to alternating cycles, as in most Madreporaria. On account of this similarity of the mesenterial arrangement the Madreporaria have been considered by writers such as Prof. R. Hertwig and Prof. McMurrich as probably belonging to the Hexactiniae, the main difference being the presence of a skeleton in the one and its absence in the other. Further minor differences can now be established, such as the presence in most Hexactiniae of gonidial grooves in the stomodaeum, and ciliated streaks (Flimmerstreifen) to the mesenterial filaments, and their invariable absence in the Madreporaria.

The mesenterial arrangement in the Zoantheae approaches somewhat that in Porites. Beyond the protocnemes the new mesenteries arise in only two regions, one on each side of the ventral directives. Further, the unilateral pairs consist of a macrocnemic and a brachycnemic moiety, as in Porites, though in the Zoantheae the brachycnemic members at no time reach the stomodaeum.

Of all Actiniaria the Ceriantheae most nearly approach the condition in Porites. For here the mesenteries beyond the four Edwardsian pairs (?) arise as bilateral pairs at the dorsal region of the polyp, each within the entocoele of the previously-formed pair. The bilateral pairs are all complete, and apparently no incomplete protocnemes are ever developed. The Ceriantheae, therefore, bear much the same relation to the Hexactiniae which Porites does to the rest of the Madreporaria; and in any classification of the latter, based upon the morphology of the polyps, Porites should receive recognition equal to that accorded Cerianthus among the Actiniaria.

The Protosepta.

Prof. Lacaze-Duthiers (1873) was the first to observe the origin of the primary septa in coral larvae, his researches being conducted upon *Astroides calycularis.* Twelve independent septa were found to appear simultaneously, one in each mesenterial chamber, while the larvae was at the protocnemic stage of development. Prof. G. von Koch (1882) subsequently obtained similar results for this species, at the same time fully establishing the ectodermal origin of the skeleton. Von Koch's (1897) recent paper on the development of *Caryophyllia cyathus* indicates that in this coral the six entocoelic septa alone are the first to appear, the alternating exocoelic septa arising later. Here again the protocnemes alone are developed, the fifth and sixth pairs being incomplete. Prof. Lacaze-Duthiers (1897) in his latest work on corals, has made other contributions to our knowledge of the early stages in the development of the septa. A very complete series, illustrating the appearance of the septa in *Balanophyllia regia*, as well as notes on Caryophyllia and other species, are given. The corals Leptopsammia, Cladopsammia, in addition to Astroides and Balanophyllia, are stated to possess twelve primary septa.

My observations on the young polyps of *Manicina areolata* correspond somewhat with those of Lacaze-Duthiers and von Koch. The first six septa appeared simultaneously within the entocoeles of the larva, at the stage with twelve mesenteries (Fig. 1). No indications were afforded of any exocoelic septa, although a considerable interval elapsed between the appearance of the septa and the preservation of the young polyps. Studies of later stages in the development of the young polyps and of the adult colonies demonstrate, however, that at no stage do exocoelic septa appear in Manicina.

The simultaneous appearance of the six or twelve protosepta in larvae or young polyps, is thus in marked contrast with the successive order of development of the pairs of protocnemes. The septa only appear when these latter have attained the Edwardsia stage, with the fifth and sixth pairs incomplete. Likewise in polyps arising by gemmation, as I have found in Madrepora, the six pairs of protocnemes are established before any corresponding septa make their appearance; so that it seems likely the protosepta arise simultaneously also in asexually produced polyps.

The Metasepta.

An interval of several weeks in the life of the young polyp may elapse between the completion of the protocnemes and protosepta and the appearance of the metacnemes and metasepta. Neither in the works of Prof. Lacaze-Duthiers nor of von Koch are the metasepta traced as regards their association with the mesenteries. For what follows, therefore, we shall be dependent upon results obtained from asexually-produced buds; but there seems no reason for supposing that the order is here different from that in sexually-produced polyps.

First, it may be stated that the metasepta are found to appear in pairs, practically simultaneously with each pair of metacnemes, not, like the protosepta, a cycle at a time. Therefore the actual order of succession already determined for the mesenteries is that followed by the septa, and need not be again repeated. It is indicated in Fig. 12. Good preparations showing the early metasepta in association with the first-cycle metacnemes, are difficult to obtain, and the stages are rarely regular on both sides of the polyp. From both *Cladocora arbuscula* and *Solenastraea excelsa* various series of preparations of young polyps have been secured, which prove conclusively that with each pair of metacnemes there is early associated two additional septa—one within the entocoele of the mesenteries and one within the exocoele on the dorsal or ventral aspect, as the case may be. The entoseptum may appear slightly in advance of the exoseptum, and soon exceeds the latter in size. In Fig. 4 both entocoelic and exocoelic septa are already present along with the four pairs of second-cycle metacnemes, although the latter are very small. Each entoseptum has its corresponding exoseptum, and it is obvious that the two last cycles of septa are both incomplete numerically.

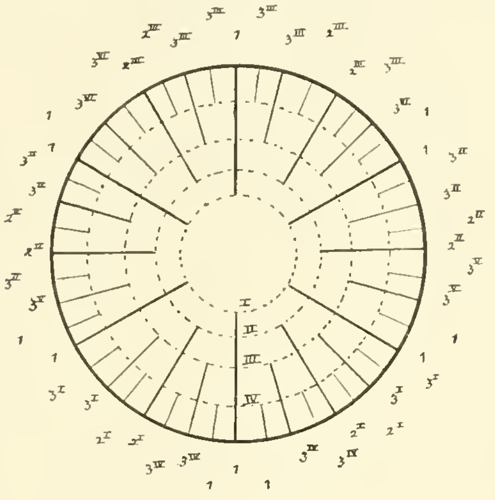

FIG. 12.

Diagram to illustrate the order of appearance of the septa in a coral polyp with four complete cycles of septa, based on the supposition that an entocoelic and an exocoelic septum arise with each new pair of mesenteries. In relation to the mesenteries the three inner cycles are entocoelic and the last is exocoelic. The first cycle of six entosepta (1-1) appear simultaneously, and also the corresponding six exosepta, now in the last cycle. The members of the second cycle of six entosepta (2I, 2II, 2III) appear successively from one aspect of the polyp to the other, along with the corresponding exosepta in the last cycle. The members of the third cycle of twelve entosepta (3I.-3VI.) appear successively from one aspect of the polyp to other, but the pairs 3I, 3II, 3III on the dorsal aspect of the second-cycle septa are completed before pairs 3IV, 3V, 3VI arise on the ventral aspect of the second-cycle septa. The last cycle of twenty-four exocoelic septa is constituted of members which have appeared in association with the previous septa in the order indicated in the outer cycle of numerals. The corresponding septa on opposite sides arise practically together and are so indicated.

In nearly all corals with several hexamerous cycles of septa it is found that the first cycle of six occurs within the entocoeles of the six pairs of protocnemes, the second cycle within the entocoeles of the six pairs of first-cycle metacnemes, the twelve septa of the third cycle within the twelve pairs of second-cycle metacnemes, and so on; but the septa of the last cycle are exocoelic. In the fissiparous genera Manicina, Maeandrina, Isophyllia, and Favia exosepta are generally wanting; only entosepta are present.

It has already been shown that where in the young polyp two cycles of protosepta occur, the six forming the first cycle are entocoelic, and the six forming the second cycle are exocoelic; whereas in all older polyps the second cycle of septa is entocoelic, and only the last is exocoelic. An important question in Madreporarian morphology therefore arises, namely, what is the relation of the newly added mesenteries to the already existing exocoelic protosepta? Does each new pair of mesenteries grow downwards from the column-wall so as to include an exoseptum within its entocoelic chamber, and then two new exosepta arise on each side; or does the new pair of mesenteries come to be situated on one side of an exoseptum, that is, in the chamber between an exoseptum and an entoseptum, and a new entocoelic and exocoelic septum arise in association therewith? I have as yet been unable to obtain decisive evidence in proof of either view. Many facts seem to point to the latter method as being the one actually followed, in which case it will be necessary to take an altogether different conception of the relations of coral septa from that usually accepted. With whatever cycle of mesenteries the exosepta are primarily formed they will all be relegated in the mature polyp to the last cycle, and all the previous cycles of septa will be entoseptal from the beginning. The septal cycles will then correspond in order of appearance with the cycles of mesenteries with which they are associated. On this view the order of appearance of the septa for a polyp with four cycles—three entocoelic and one exocoelic—will be as represented in the annexed diagram (Fig. 12).

This is actually the relationship which Prof. Lacaze-Duthiers, and later Dr. L. Faurot (1895), have established for the tentacles of the Actiniaria, and I find it to be the same for the tentacles of the Madreporaria. As is now well known the Actinian tentacles beyond the primary twelve appear two together, along with each new pair of mesenteries. Of the two tentacles one is entocoelic and the other exocoelic in relation to the new mesenteries. The former becomes the larger and takes its place in the tentacular cycle corresponding with the mesenterial cycle with which it is associated; the latter, the exocoelic tentacle, is relegated, as it were, to the last cycle of tentacles, and becomes uniform in size with the other exocoelic tentacles.

The problem of the septal sequence may be restated as follows: Do the septa beyond the primary series arise as exocoelic pairs, or, like the tentacles, is each new pair constituted of an entocoelic and an exocoelic member?

The view emphasized by Milne-Edwards and Haime in their classic "Coralliaires," and practically followed by all subsequent students of corals, is that the magnitude of the septal cycles in general corresponds with their age, the smallest cycle being the youngest. Accepting this we shall have to believe that as new mesenteries are added the pairs embrace the exosepta of the previous cycle, and then two new exosepta arise, one on each side of the new mesenteries; the new mesenteries of the next cycle in their turn would enclose the exosepta within their entocoeles, other exosepta would then be formed, and so on. In other words, the exosepta of one cycle of mesenteries become the entosepta of the next cycle of mesenteries.

Probably only a study in the larva or young polyps of the actual formation of the metacnemes and metasepta in their relation to the protosepta will determine which of these courses is followed.

METASEPTA IN PORITES.

The metacnemes in Porites have been described as arising in bilatear pairs, at one or the other aspect of the polyp. In all cases the metasepta are found to follow in close succession, an entocoelic and an exocoelic representative on each side. In such small corallites as are characteristic of the genus under consideration, the septa are not favourable for study; but there does not appear to be much difference in size among them. However, from their manner of development there can at most be only two orders represented—entocoelic and exocoelic. A multicylic hexamerous condition, such as is characteristic of most other recent corals, would be impossible.

The bilateral symmetry of the septa, the alternation of only large and small members, and their growth from one or more special regions, are all characters of primary importance among many of the extinct Palaeozoic corals, and, sometimes with a tetrameral arrangement, serve to sharply distinguish these from modern cyclical corals. There can be no doubt that in Porites we have a living example in which the metacnemes and metasepta arise in the same manner as in many of these old time corals.

Even where in fossil or recent corals the adult arrangement of the septa is tetrameral or octameral, examination by means of sections sometimes reveals a primary hexameral condition. All evidence goes to show that the protoseptal phase has always been hexameral in the Zoantharia, and that it is only with the appearance of the metasepta that the distinctive characteristics—cyclical (tetrameral, hexameral, etc.) or bilateral—truly commence. The arrangement of the mesenteries and septa on the cyclical or bilateral plan should, in my opinion, constitute the basis for a primary subdivision among the great group of corals.

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The Arterial Circulation of Nautilus Pompilius. By LAWRENCE EDMONDS GRIFFIN.

The figures of the arterial circulation have been made partly from my own dissections, and partly from the published figures and descriptions of Willey. In some instances I had obtained the same results as Willey before he published his figures, in others I have merely verified his work, and in places I rely entirely upon his figures and descriptions in order that my own descriptions may be as complete as possible. Some facts are, I think, published for the first time.

In both figures of the arterial system the arteries are viewed from the dorsal side. As the vessels represented in Figure 2, lie almost entirely ventral to those of Figure 1, I believe that they are shown with less danger of confusion in separate figures than in a single figure.

The heart is situated immediately back of the mantle fold in the portion of the cœlom known as the pericardium. It is an oblong, muscular organ of quite considerable size, being 2 cm. in width, 1 cm. in length (antero-posterior measurement), and 6 mm. to 8 mm. in thickness. The long axis of the heart is exactly transverse to the long axis of the body. The right side of the heart is slightly longer than the left side, so the symmetry of the heart is not quite perfect.

A branchial vein enters each corner of the heart. The portion of each branchial vein near the heart is capable of considerable distension, and these portions have been called the auricles of the heart. But very frequently one or all these vessels show no increase in diameter near the heart. This fact indicates that the so-called auricles of Nautilus, while physiologically similar, have not the same morphological importance, and should not be considered as organs of the same nature as the auricles of the heart of the Gastropoda and the Lamellibranchiata. In these classes the auricle forms a distinct chamber which even in its development is distinct from both the ventricle and the branchial veins, which the auricles of Nautilus are not. The term auricle is a convenient one anatomically, indicating the portion of the branchial vein inside the pericardium, which is evidently distensile and pulsatile, but it should probably not be used in the same morphological sense as in the other groups mentioned.

Five vessels arise from the dorsal side of the heart, the courses of which will be described presently.

The heart has thick muscular walls, and, in the contracted state consequent upon death, a very small fissure-like cavity. The inner surface of the heart is pitted, and by its appearance reminds one strongly of the inner surface of a mammalian heart, though by no means distinctly trabeculated. I have not been able to find any valves at the openings of the vessels leading into or from the heart, except possibly the dorsal aorta. The openings are, however, tightly closed, and it is possible that at the commencement of systole the walls of the heart contract first around the openings of the branchial veins and thus the regurgitation of blood is prevented.

The largest vessel proceeding from the heart is the dorsal aorta.[1] This arises from the dorsal surface of the heart, on the left side and near the posterior edge (31). The base of the aorta is conical and possesses thick muscular walls, and could probably be properly spoken of as a conus arteriosus. At the end of the muscular portion of the base of the aorta is an elevation of the inner wall which may be a valve. In some specimens this is quite distinct and much like a semilunar valve; in others it is barely noticeable. Possibly the conical base of the aorta should be considered morphologically as a portion of the heart itself.

Along the median part of the posterior edge of the heart, dorsally also, arise three small arteries. They lie in the portion of the pallio-visceral ligament attached to the posterior side of the heart. The artery at the left is the artery of the pyriform sac (36); the middle one is the genital artery (24); while the one on the right is the gonaducal artery (21).

Also from the dorsal side of the heart, but near the anterior edge, arises the fifth artery, the lesser aorta.

Let us now follow the course of the dorsal aorta and its branches, (Fig. 1.) From its origin on the dorsal side of the heart the aorta extends upward and backward and to the left along the posterior side of the hæmocœlic membrane.[1] Turning forward it penetrates the membrane and enters the hæmocœl, in which it lies free, running forward over the liver and the œsophagus. In the posterior portion of the hæmocœl the aorta lies well to the left of the cavity, but as it extends forward it approaches the median line until, near the œsophageal nerve ring, it lies in the median line (43). Immediately back of the nerve ring the aorta divides into a left and a right branch, the innominate arteries, from which lesser branches are given off to the cephalic region and the funnel (9).

Proceeding from the posterior end of the aorta, the first branch leaves it just after the aorta enters the hæmocœl. Coming off from the right side of the aorta, it runs toward the right side of the body, giving off first a branch anteriorly which passes to the posterior portion of the proventriculus, the posterior proventricular artery (33); next, a branch posteriorly which immediately bends forward and passes around the anterior side of the stomach to the cœcum, the cœcal artery (28); finally, the end of the artery passes to the stomach, forming the gastric artery, which breaks up into numerous fine vessels in the walls of the stomach (27).

Five or six millimeters anterior to the origin of this artery a much larger artery leaves the left side of the aorta (34). After a course of about five millimeters this artery divides into two branches, the anterior of which goes to the left shell muscle, (the left posterior columellar artery, 37), while the posterior branch proceeds to the liver (hepatic artery, 32). I have called the branch of the aorta from which both these arteries arise the hepatico-columellar artery.

The hepatic artery goes to the junction of the two left lobes of the liver. It divides here into three branches. The left and middle branches enter the left lobes of the liver in which they break up into the fine lobular branches (30). The right hand branch of the hepatic artery follows the median connecting portion of the liver to the junction of the two right lobes of the liver. Here it divides into a branch for each lobe (25). Along its course it gives off a considerable branch to the median portion of the liver (29).

The left posterior columellar artery runs forward and upward to the dorsal edge of the left shell muscle near its attachment. After giving off a branch to the dorsal portion of the body wall it bends downward along the inner surface of the shell muscle, giving off numerous branches which enter the muscle (38).

The right posterior columellar artery (18) arises from the right side of the aorta about five millimeters anterior to the origin of the hepatico-columellar artery. Since the posterior portion of the aorta is upon the left side of the body cavity the right posterior columellar artery is considerably longer than the corresponding left artery. The course of the right posterior columellar artery is the same, only inverted, as that of the left.

About twenty millimeters anterior to the origin of the last artery the right pallio-nuchal artery arises as a branch of the aorta (16). The left pallio-nuchal artery (39) arises from the aorta four or five millimeters anterior to the right pallio-nuchal. These arteries pass upward and outward to the dorsal side of the body, entering the body wall at the base of the mantle fold where the latter crosses the dorsal edges of the shell muscles. Several branches leave the pallio-nuchal arteries at this point. Some of these pass into the dorsal portion of the mantle lying against the involution of the shell (42). The main portion of each artery is continued in the thin wall of the dorsal nuchal region, supplying especially the crescentic fold upon the posterior face of the hood (13). As it passes along the edge of the shell muscle it appears to send some small branches into the tissues of the muscle. A considerable branch extends into the crus of the funnel (14). From the outer side of the pallio-nuchal artery a branch enters the mantle which becomes continuous with the marginal pallial branch of the anterior pallial artery (15, 40).

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[1] Until otherwise indicated all references will be to Figure 1.

[1] This is the membrane which, stretched transversely across the body, separates the hæmocœl from the cœlom.

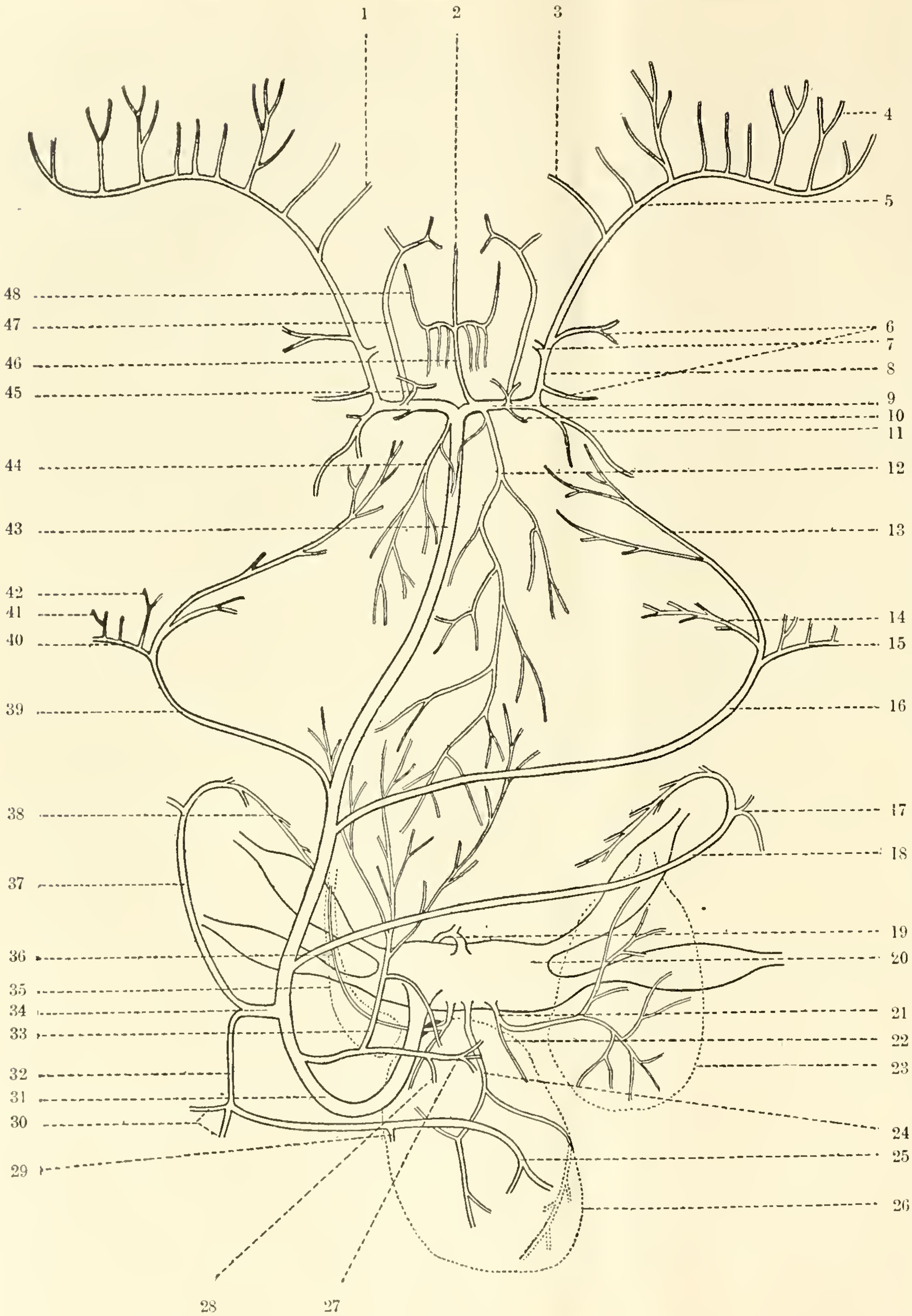

Fig. 1.

1, left artery of Van der Hoeven's organ in the male; of inferior labial lobe in female. 2, superior mandibular artery. 3, right artery of Van der Hoeven's organ in male; of inferior labial lobe in female. 4, artery to individual tentacle. 5, right tentacular artery. 6, arteries of eye. 7, infundibular artery. 8, pedal artery. 9, innominate artery. 10, artery entering posterior part of hood. 11, right anterior columellar artery. 12, right anterior proventricular artery. 13, nuchal artery. 14, crural artery. 15, marginal pallial artery. 16, right pallio-nuchal artery. 17, branch to dorsal body wall. 18, right posterior columellar artery. 19, lesser aorta. 20, heart. 21, gonaducal artery. 22, branch to wall of gonad. 23, outline of genital duct. 24, genital artery. 25, artery of right lobes of liver. 26, outline of gonad. 27, gastric artery. 28, coecal artery. 29, artery to middle portion of liver. 30, arteries to left lobes of liver. 31, dorsal aorta. 32, hepatic artery. 33, posterior proventricular artery. 34, hepatico-columellar artery. 35, outline of pyriform sac. 36, artery of pyriform sac. 37, left posterior columellar artery. 38, descending portion of columellar artery giving off branches to muscle. 39, left pallio-nuchal artery. 40, marginal pallial artery. 41, radial pallial artery. 42, artery to dorsal portion of mantle. 43, dorsal aorta. 44, left anterior proventricular artery. 45, cerebral artery. 46, buccal artery. 47, inferior mandibular artery. 48, labial artery.

Usually no other vessels arise from the aorta until it divides into the innominate arteries.

The anterior proventricular arteries (12, 44), supplying blood to rather more than the anterior half of the proventriculus, frequently arise from the junction of the aorta with the innominate arteries. These arteries are, however, extremely variable in their position, a fact to which Willey has called attention. One or both may arise from the innominates quite to the sides of the aorta, or one may be entirely absent. In Willey's Fig. 23,[1] the left anterior proventricular artery arises from the aorta a considerable distance below its division into the innominate arteries. Two small arterioles going from the anterior proventricular arteries to the walls of the aorta also show considerable variation in their points of origin. Ordinarily one arises from the base of each proventricular artery. In the case figured by Willey both arterioles arise from the right anterior proventricular artery, the left proventricular artery being absent in this case.

The buccal artery (46) usually springs from the right innominate close to its separation from the left. It passes forward upon the dorsal side of the buccal mass, presently dividing into three branches. The median branch, the superior mandibular artery (2), runs straight forward in the median line of the buccal mass, giving off branches to the superior mandibular muscles. The lateral branches first pass outward to the sides of the buccal mass, giving off on the way several small branches posteriorly to the mandibular muscles, then turn forward and pass into the buccal membrane and its papillae (48). The branches of the buccal artery are, however, very variable in the manner of their distribution. Of the origin of the buccal artery Willey says, "It is a singular fact that the great median buccal artery always springs from the right innominate artery. The constancy of this origin would seem to indicate that it is potentially a paired structure." I have dissected specimens in which the buccal artery sprung from the junction of the innominate arteries; in other words, was median. Either position, lateral or median, may be secondary, resulting from a displacement of the base of the artery during growth, and it is difficult to decide which is primitive without the evidence of embryology.

Five or six millimeters from their junction a branch arises from the anterior side of each innominate (the inferior mandibular artery, 47) which runs forward on the under side of the buccal mass to the muscles and organs of the floor of the pharynx. These arteries are closely bound to the buccal nervous system, careful dissection being required to separate the arterial from the nervous elements. The inferior mandibular arteries supply not only the lower parts of the mandibular muscles but also the tongue and the radular sac, the processes anterior to the tongue, and the salivary processes.

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[1] Quart. Journ. of Micr. Sci., Vol. 39.

From the dorsal side of the innominates, near the origins of the inferior mandibular arteries, arise arterioles which pass into the cerebral ganglia (45). From the posterior side of the innominates other small vessels pass into the posterior portion of the hood (10).

Finally, each innominate divides, one branch passing backward into the shell muscles and forming the anterior columellar artery (11), the other branch passing forward and downward along the bases of the tentacles, forming the pedal artery, (8) Willey. Near the base of the pedal artery two arterioles pass outward to the eye (6). Between these a large branch arises from the pedal artery which passes to the funnel, the infundibular artery (7). The remainder of the pedal artery which gives off branches to the individual tentacles Willey has very conveniently named the tentacular artery (5). The first of the branches of the tentacular artery passes into the inferior labial lobe in the female, and into Van der Hoeven's organ in the male (1, 3).

The origin of the genital and gonaducal arteries and the artery of the pyriform sac has already been mentioned.

The genital artery passes from the heart directly back upon the gonad, in which it breaks up into capillary branches (24).

The gonaducal artery passes to the right from the heart and is distributed to the walls of the functional genital duct (21).

The artery of the pyriform sac, or the non-functional genital duct, passes to the left from the heart and extends along this organ (36).

Willey shows that both the gonaducal artery and the artery of the pyriform sac give off a branch which passes into the perigonadial membrane (22), and he says, "this apparently trifling fact, combined with the subsymmetrical relations of the gonaduct and the pear-shaped gland, may indicate that the latter is the metamorphosed genital duct of the left side, and not, as I believe has been suggested, the morphological equivalent of an entire left genital apparatus."

Almost immediately after its origin from the anterior side of the heart the lesser aorta (17) divides into two branches.[1] One, the anterior pallial

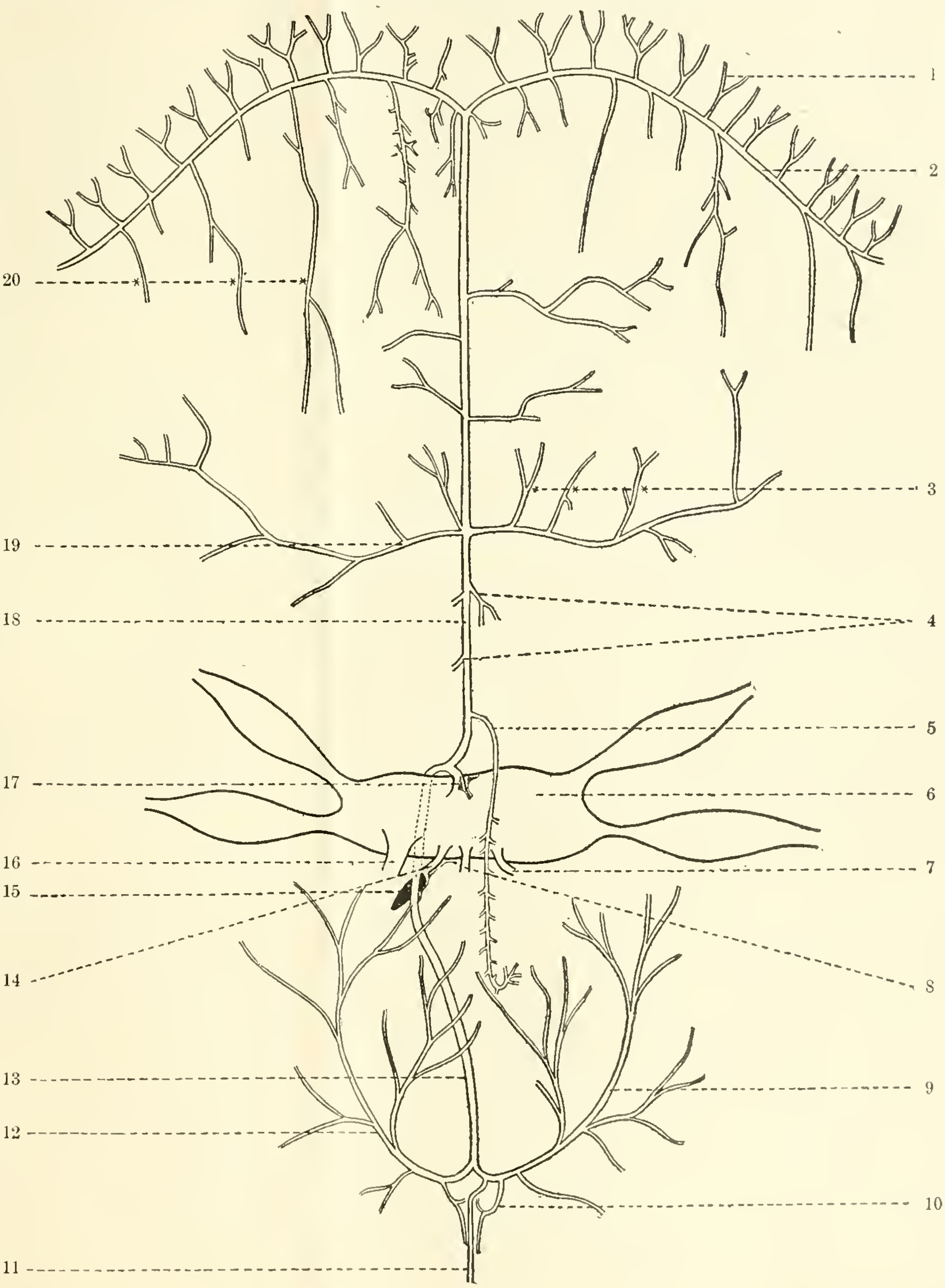

FIG. 2.

1, radial pallial artery. 2, marginal pallial artery. 3, arteries of nidamental gland. 4, rectal arteries. 5, intestinal artery. 6, heart. 7, gonaducal artery. 8, genital artery. 9, right septal artery. 10, accessory siphuncular artery. 11, siphuncular artery. 12, left septal artery. 13, posterior pallial artery. 14, artery of pyriform sac. 15, posterior viscero-pericardial opening. 16, dorsal aorta. 17, lesser aorta. 18, anterior pallial artery. 19, branchio-osphradial artery. 20, median pallial arteries.

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[1] The arteries described after this are represented in Fig. 2.

artery (18), runs straight forward in the median line of the mantle and is distributed to the intestine, rectum, and mantle. The other, the posterior pallial artery (13),[1] runs almost straight backward and is distributed entirely to the septal portion of the body wall and the siphuncle.

The anterior pallial artery is enclosed by the pallio visceral ligament. A few millimeters anterior to the heart it gives off a slender branch (the intestinal artery, 5) which runs back in the membrane uniting the two portions of the second loop of the intestine. Small arterioles pass from either side into the intestinal tissues.

In front of the intestinal artery several small rectal arteries (4) arise directly from the anterior pallial artery and pass to the walls of the rectum.

At the point where the two walls of the mantle fold unite, and the mantle becomes thin, a pair of vessels arise from the anterior pallial artery and pass outward to the right and the left in the substance of the mantle (19). These arteries, discovered by Willey, were called by him the branchio-osphradial arteries "since among their minor ramifications they send up branches to the tips of the branchiae supplying the integument of the latter, and also a small branch into each of the osphradia." In the female the nidamental glands are supplied by branches of the branchio-osphradial arteries (3). I retain the name "branchio-osphradial" for these arteries because although the osphradial character of the papillae referred to is not yet well proven there is still a considerable probability of it, and it does not seem worth while to burden the literature of the subject with a new name which *might* in time prove more correct, but for the present would be no more intelligible or convenient.

The anterior pallial artery now passes forward nearly to the edge of the mantle. It here divides into a right and a left branch (the marginal pallial arteries, 2) which run parallel to the edge of the mantle till they unite dorsally with the pallio-nuchal branches of the dorsal aorta. In this way a remarkable arterial circuit is formed to which Willey has given the name "circulus pallialis."

From the anterior side of the marginal pallial artery a regular series of small arteries (1) pass into the portion of the mantle in front of the marginal artery, which we have noticed to be especially muscular and slightly thicker than the middle portions of the mantle.

From the posterior side of the marginal artery, and from the anterior portion of the anterior pallial artery numerous vessels pass into the middle portions of the mantle (20).

The posterior pallial artery (13) bends around the anterior side of the heart immediately after its origin and then passes backward along the ventral surface of the heart. It is here covered by the portion of the pallio-visceral ligament which encloses the heart, and hangs suspended in a mesentery-like fold of this ligament. Running backward under the left side of the heart the artery arrives at the posterior viscero pericardial opening (15), through which it passes by following the right edge; this edge being attached to the gonad, the artery passes directly upon the surface of the ovary or testis, as the case may be. Passing over the lower edge on to the anterior face of the gonad, the artery reaches the gastric ligament, along the edge of which it passes to the posterior wall of the body near the base of the siphuncle. The posterior pallial artery does not appear to give off any branches to the gonad.

Arrived at the posterior wall of the body the artery divides into a right and a left septal artery (9, 12). These ramify over the portion of the body wall which faces the septum. It will be remembered that this portion of the body wall is bounded by the dorsal and the posterior ventral aponeurotic bands. The branches of the septal arteries are rigidly confined to the septal area of the body wall.

The siphuncular artery (11) arises as a branch of one of the septal arteries, sometimes of one, sometimes of the other. Entering the base of the siphuncle the artery extends through it to the end. Other smaller branches of the septal arteries may also enter the base of the siphuncle (10).

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[1] This name, given by Willey, is entirely improper, since the artery is distributed to the body wall and not to any portion of the mantle.

The Anatomy and Development of the Reproductive Organs of Planaria maculata. By Winterton C. Curtis.

During the summers of 1898 and '99 while at the Marine Biological Laboratory, Wood's Holl, Mass, I became interested in studying the common *Planaria maculata* which is abundant in almost every fresh water pond about the town. Some very large specimens 15-20 mm. in length, were found in the ponds near Falmouth and with them large numbers of eggs, which they lay during May and June. Reproductive organs were of course fully developed in these specimens and I studied their anatomy casually while endeavoring to ascertain new facts regarding the function of the uterus, penis, etc., during the egg-laying. At this juncture I was surprised to read in a recent paper by Woodworth the following sentence, "*Planaria maculata* is the commonest of our fresh water Planarians and was the first one to be described (Leidy, 1848); however, nothing has been published regarding its sexual organs, and I am unable to offer anything in this regard; not one of the hundreds of specimens that came under my observation was sexually mature."[1]

Since the anatomy of the most complexed system of organs in this common species is entirely unknown or at least unrecorded, I have availed myself of the opportunity to study carefully the reproductive organs in their fully developed state and find out if possible why so many individuals have been observed, by Woodworth and others, with no trace of reproductive organs. In September of 1899 I collected small specimens in the vicinity of Baltimore, which, upon examination, were found to have their reproductive organs just developing. This paper aims merely to state the facts thus far ascertained regarding the development and adult condition of these organs.

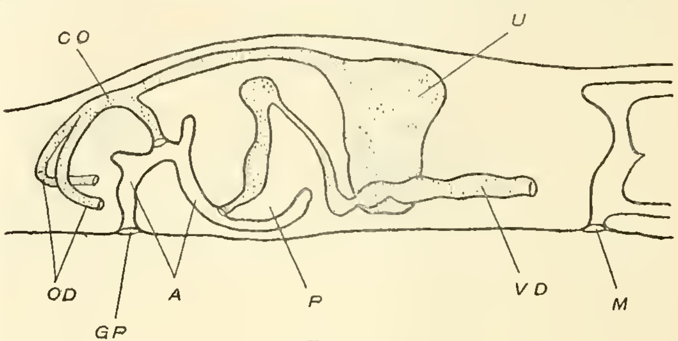

Fig. 1.

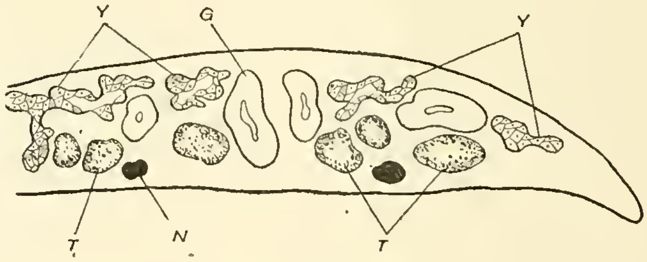

Fig. 2.

The general arrangement does not differ greatly from what has been found repeatedly in other Planarians. The testes are very numerous and extend from the region of the oviducts almost to the tail. Though a few large follicles are to be found extending up between the gut lobes, the rest are packed closely together in the ventral region and never found dorsal to the gut. Their lateral extent is seen in transverse section of the animal (Fig. 2), to be from a point about half way between the lateral margin of the animal and the nerve cords to within a short distance of the median line. Everywhere they are close together and from the ovaries to the tail hardly a section can be found that does not cut a half dozen or more. In longitudinal sections they are arranged one after another like a row of billiard balls; there are something like 75 on either side.

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[1] I. Contributions to the Morphology of the Turbellaria. Bull. Mus. Comp. Zool., Harvard College, Vol. XXXI., No. 1. Contributions to the Morphology of the Turbellaria. II. On some Turbellaria from Illinois, Vol. XXXI, No. 1.

Testicular canals (vasa efferentia) are everywhere found connecting one testis with another or in the region of the pharynx connecting the testes with the vasa deferentia. It has seemed to me in studying these fine canals that there is no reason for doubting that each testis has a definite connection either directly or through intervening testes with the vas deferens. In forms with a smaller number, each testis connects with an elongated vas deferens. In *Planaria maculata* the testes communicate with one another and ultimately with the vas deferens. During the egg-laying season the vasa deferentia are so distended by spermatozoa as to form large seminal vesicles extending as far forward as the front end of the pharynx. Here they decrease suddenly in diameter and can be followed only a very short distance farther. Practically the whole vas deferens has been converted into a seminal vesicle. In the live worm they may be seen through the ventral surface as two whitish masses on either side in the region of the pharynx. Posteriorly the seminal vesicles narrow suddenly and the fine tubes thus formed turn with a sharp angle and mount dorsally to the base of the penis where they unite to form the penis lumen. This lumen is of considerable size, but opens by a much smaller aperture.

The penis (Fig. 1, *p*) is short and thick, closely invested by the walls of its cavity and pointing downward and backward at an angle of about 45°. Behind this anterior part of the atrium which contains the penis, the atrium is narrowed abruptly so that it becomes a canal leading straight back. It is worth noting that the longitudinal axis of the penis does not point in the direction of this opening but downward and backward as above described, and thus the free end of the penis lies somewhat below the opening through which it must pass when protruded. The length of this narrow canal is usually equal to about one half the diameter of the penis. It then sends off a canal of equal diameter downward and slightly backward which communicates with the outside at the genital pore. A similar part, the vagina, extends dorsally pointing backward at a small angle. This reaches almost to the basal membrane on the dorsal side before it splits into the stalk of the uterus running forward and the common oviduct running backward on the mid-line (Fig. 1.) The posterior surface of the vagina is thrown into one or two large folds which run lengthwise and sometimes appear like a miniature penis. There is, however, no such structure and the atrial cavity is no farther complicated than by the division into an anterior portion containing the penis and a posterior which receives the female elements. Besides the secretion of the unicellular glands surrounding the atrium its epithelial lining seems to be actively at work producing a secretion which appears as spherical masses detaching themselves from the cells and covering the surface several layers deep.

The stalk of the uterus as above mentioned extends forward from the vagina along the mid-line as a small tube which in many places shows indications of contraction or rather the possibility of dilatation for the outline of its lumen is folded. In front of the penis it expands into a spherical cavity, the uterus, such as is found in many Planarians (Fig. 1, *u.*) During the egg-laying season, this cavity, when seen in transverse section, is as large as the pharyngeal pocket and extends right up to the dorsal and ventral basal membranes. Within the uterus I have found masses of spermatozoa, and in some cases the egg-capsule in process of manufacture. Almost every live specimen when looked at from the ventral side shows a reddish brown mass in the position of the uterus, as though the uterus contained one of the brown egg-capsules. This color is, however, usually due to the color of the uterus itself for it shows exactly the same when there is no trace of a capsule within.

Opposite the place where the uterus stalk leaves the vagina the common oviduct leads off posteriorly. It very soon divides and each oviduct extends forward just above the nerve-cord as in other forms. What I have seen of the oviduct leads me to think that it is in the same condition as the stalk of the uterus, viz. capable of great distention. Its appearance is like that of all planarian oviducts, but because of its functional activity at this season it seems to give a clearer indication of what kind of a tube the oviduct really is. While I have not yet found ova in the ducts of any specimens, the lumen must be greatly enlarged to permit the passage of the ova and the large numbers of yolk cells which proceed down it to the uterus. If a tube having a lumen sufficiently large for this should contract in such a way that an inner part which lined the lumen did the contracting, while the remaining thickness accommodated itself to this change, we should have a cylinder fluted on the outside and with a denser substance immediately surrounding a small internal cavity. This is what the planarian oviduct is like, and I believe the above explanation is a reasonable one.

The yolk-glands are connected with the oviduct everywhere along its length and their cavities open into its lumen. Only one kind of cell is to be found in the ripe yolk-glands and these are loose in the cavity like so many enormous spermatids in a testis. These yolk-glands extend everywhere, filling the space on the dorsal side and between the gut-lobes so completely that there seems little room left for parenchyma. As they are kept out of the ventral region by the numerous testes the result is that the yolk-glands are dorsally placed. They do not have any definite position like the testes which remain in that part of the parenchyma where they first appear, but seem rather to have grown in and taken all the space that was left. Anteriorly they extend only a short distance in front of the ovary, but like the testes extend back almost to the tail.

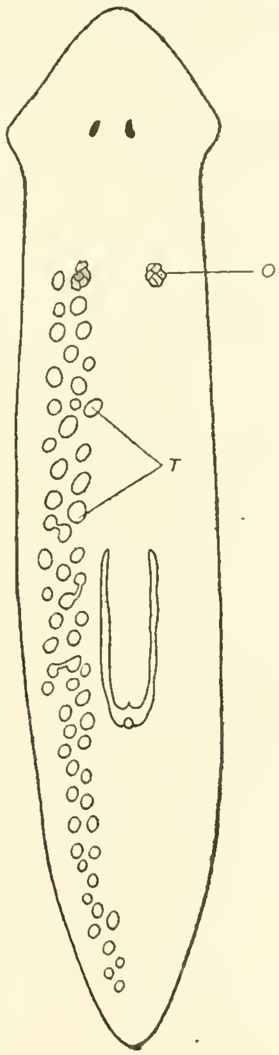

Fig. 3.

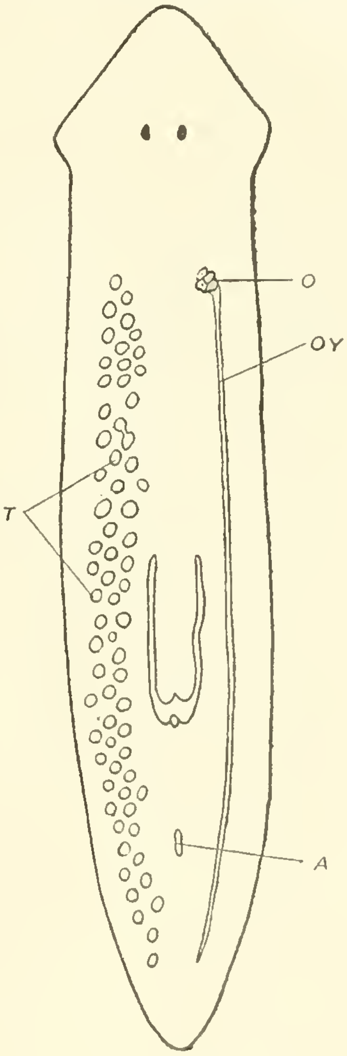

Fig. 4.

The ovaries which lie one-fourth the entire length of the animal from its anterior end are in the usual ventral position above and inside the nerve-cord. They are of considerable size, often more in diameter than one-half the dorso-ventral thickness of the worms. The ova are of all sizes, the largest being found in the center almost within the head of the oviduct and entirely free, evidently already for laying. Only upon the very outside are small spherical cells which probably represent the supporting frame work often described in Planarians. But there is no supporting frame work in the centre and the spherical cells of the periphery which might represent it pass by insensible stages into the smallest ova. The ovary is therefore made up entirely of ova of different sizes most of them very large and ready for their departure. The appearance of the yolk-glands and testes in a cross section of the animal is shown in Fig. 2.

There is nothing like a parovarium and the ovary is compact without irregular lobes extending into the parenchyma.

In the foregoing I have described the structure of the organs when in full activity; in the following I shall describe the stages in their development which I have observed. These were studied in small worms, 5-8 mm. in length, collected in the vicinity of Baltimore during October 1899. In the youngest specimens found the ovaries can be made out in the same relative position as in the adult. The testes also are in the same relative position and connected everywhere by short thick rods of cells which are destined to be the testicular canals. Such a stage seen from above or below might be represented by a diagram like Fig. 3. I have only one specimen of this early stage and cannot be certain whether any trace of the oviduct has made its appearance. There is no trace of the genital-atrium.

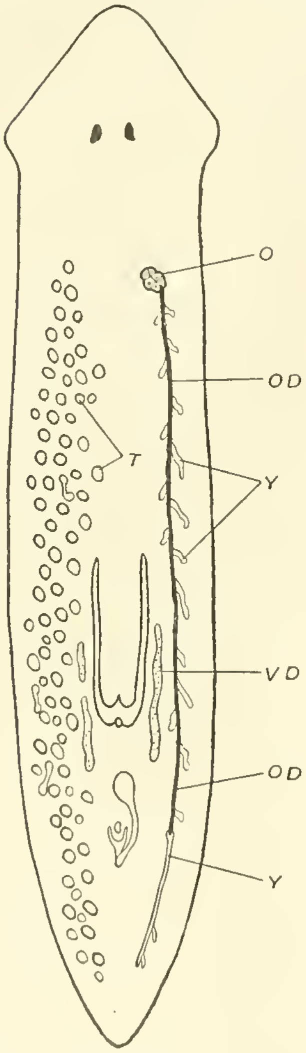

Fig. 5.

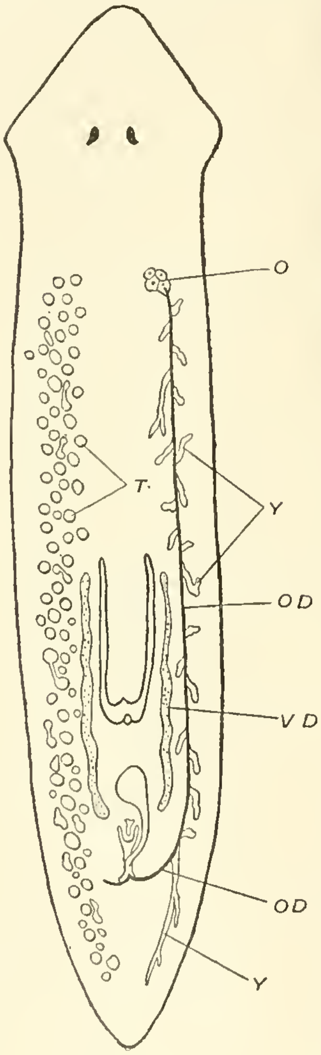

Fig. 6.

At a stage slightly older than the above (Fig. 4), there appears in the region of the genital atrium a cleft in the parenchyma (Fig. 7.) This is preceded by a noticeable collecting of parenchyma cells at the spot. Lining the cleft an epithelium is formed in the same way as in the embryo the pharyngeal pocket develops its lining. In this stage the anlage of the oviduct is unquestionably present, for extending back from the outer side of each ovary and along above the nerve-cord in exactly the position of the oviduct lies a rod of cells the structure of which is identical in appearance with the cords of large cells so familiar as the early stages of the yolk-glands. This rod of cells extends past the beginning of the atrium well down into the tail. There are at this time no other cell-cords of this sort in any part of the worm. Such a stage might then be represented by a diagram like Fig. 4.

Following this there are to be found along the line of each oviduct many cords of cells seeming to have grown out from the original rod, at any rate they are connected with the primary rod. Figure 5 is a representation of the condition which now exists. The part which is to become the oviduct has now in some places the beginning of a lumen, in others is still a solid rod of cells as at first. Posteriorly the oviduct anlage still extends back of the atrium. At this stage there seems to be the beginning of the vas deferens, for on either side, spaces like enlarged testicular canals can often be traced some distance in more than one place.

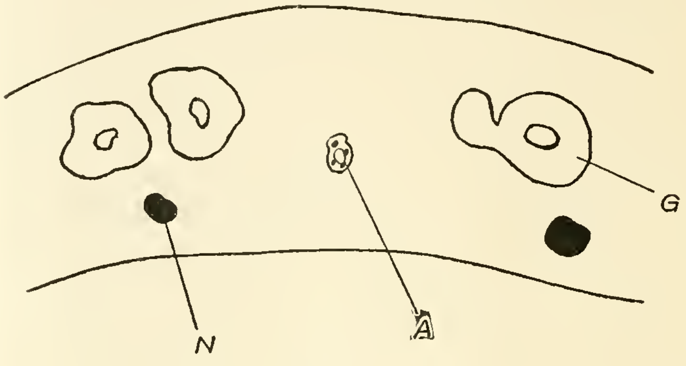

Fig. 7.

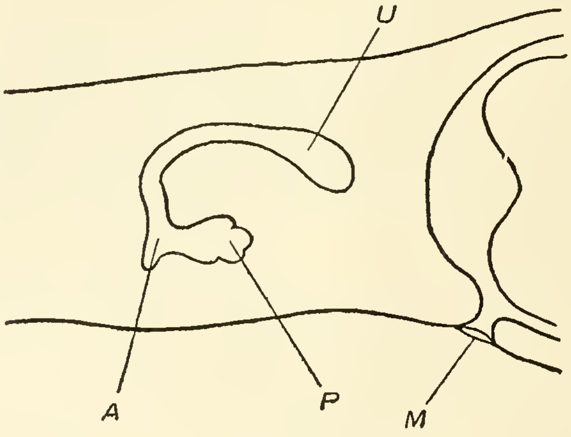

Fig. 8.

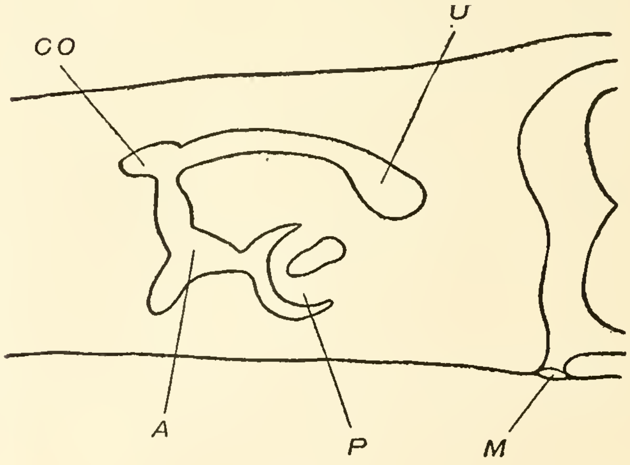

Fig. 9.

The atrium is much farther advanced in the next stage shown and can be best seen from a side view (Fig. 8). It is already divided into the penis-cavity, uterus and vagina.

The ultimate connection of the atrium to the outside, already indicated in Fig. 8, is more pronounced in a slightly later stage (Fig. 9), and from the head of the vagina opposite the uterus stalk is found an outgrowth indicating the common oviduct. The penis has also appeared and within it a cavity lined with epithelium, but this does not yet open to the outside. The vas deferens can be identified in the region of the pharynx, though it does not connect with the penis. The oviducts are found and can be identified from the ovary to the region of the atrium, where they pass into a solid cord extending toward the tail. Throughout their length they are connected at frequent intervals with the yolk-glands. There is as yet no union of either oviduct with the vagina. Figure 5 would represent the relation of the parts in such a stage.

It is but a step to the next which is practically adult. In Figure 6, there remains stretching down into the tail upon either side, a solid rod of cells now to be identified as the yolk glands of the posterior end. This is in the same position as the primary rod out of which anteriorly the oviduct was made. It can be readily traced with its connected yolk-glands as indicated in the diagram and becomes continuous with the oviduct where the latter bends inward to reach the common oviduct. The cavity of the uterus has increased in size, the lumen of the penis opens to without and the atrial-pore is formed. This is the adult condition save that the vasa deferentia are not connected with the penis lumen. The yolk-glands are much larger and pass from the oviduct up between the gut-lobes at frequent intervals.

No mention has been made in the above of the condition of the ovaries and testes for they have not changed greatly. Both are larger than at first, the ovaries with more large ova, the testes with their cavities containing spermatids of all sizes. Connecting the vasa deferentia with the penis the adult condition is reached.

There are in the development two distinct parts, the germ-cells and the accessory organs about the atrium. They originate separately and later become connected with one another. There are laid down two solid rods of cells extending from the ovaries well back into the tail. These anteriorly become the oviducts, while back of the atrium they remain the same and become yolk glands. So far as I can make out the yolk glands arise as outgrowths of these primary rods of cells. The organs of the atrium begin as a cleft in the parenchyma which gradually becomes differentiated into the several parts. I cannot determine from the material I now have whether the male and female cells originate *in situ* or first make their appearance in restricted areas and spread thence to the positions they occupy in the adult.

With regard to clearing up the fact recorded by Woodworth that very many individuals of this species are often found without reproductive organs, the solution of the problem would be best reached by observing them in one or more localities the year round. I have not been able to do this, but from the facts above noted it seems to me likely that this form does not develop its reproductive organs until a considerable time after its other organs are fully developed. I hatched the young worms from the capsule at Wood's Holl and kept them alive for several weeks, but none of them showed any sign of these organs. In October I found slightly larger worms near Baltimore developing their organs as above described. As I have seen nothing to indicate the laying of winter eggs during the fall, I conclude that the sexual products ripen slowly and in the spring the worms become very large with the approach of sexual maturity. The worms which Woodworth studied were collected mainly during the summer months, and it is not unlikely they were the young of that year, which would develop their organs in the fall. Small individuals of these species are described by Dr. Randolph,[1] who studied them at Wood's Holl, as reproducing by fission. It seems that there are some other very interesting facts to be learned in the life history of this form, and I shall try to obtain more exact data upon this problem.

EXPLANATION OF LETTERS IN FIGURES.

A.—Atrium
Co.—Common oviduct.
G.—Gut.
Gp.—Genital pore.
M.—Mouth.
N.—Nerve.
O.—Ovary.
Od.—Oviduct.
Oy.—Anlage of oviduct.
P.—Penis.
T.—Testis.
U.—Uterus.
Vd.—Vas deferens.
Y.—Yolk-glands.

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[1] Mentioned by Woodworth in the above paper.

NOTES FROM THE PHYSICAL LABORATORY.

Edited by Professor JOSEPH S. AMES.

Resistance to Ethereal Motion. By H. A. Rowland, N. E. Gilbert and P. C. McJunckin.

An attempt has been made to determine within what limits it is possible to say that there is no frictional or viscous resistance in the ether of space. Modern theories of magnetism are based on some kind of rotary or vortical motion in the ether and if a piece of iron is magnetized we imagine that the molecules, or something about them, rotate also. The existence of permanent magnets shows that any retardation due to any kind of resistance must be very slight.

In the case of an electro-magnet, any energy used in overcoming such resistence, if it exists, must be derived from the exciting current and the disappearance of such energy will produce an apparent resistance added to that of the wire. An attempt was therefore made to determine whether a wire carrying a current had the same electrical resistance when producing a magnetic field that it had when not producing it.

The experiment consisted in winding two coils of wire together on an iron core and determining whether the resistance was the same in two cases:—

(1). When the current was so passed through the coils that both produced a field in the same direction.

(2). When the current was so passed that the fields produced counterbalanced each other.

The great difficulty in the experiment lay in the necessity of measuring the resistance of a coil in which a comparatively large current was flowing. In order to overcome the effect of changes in resistance due to changes in temperature, two coils were wound, as nearly as possible identical, and these double coils were used for the four arms of a Wheatstone's bridge so that the temperature would rise in all four arms equally. Each coil consisted of about 2,500 turns of doubled No. 30 copper wire, the whole enclosed in an iron case, boiled in wax for five hours and cooled in a vacuum. The insulation resistance was then about eleven megohms. Iron cores were used and it was found that the cases effectually protected the coils against sudden changes in temperature due to air currents as well as serving for yokes to the magnets. A current of one-tenth ampere was used which insured a high state of magnetization in the iron when two coils were in series, giving 5,000 turns.

The coils were connected in the bridge in such a way that the two coils in one case formed the opposite arms of the bridge. By means of a reversing switch the current in one of these coils could be reversed. This changed the field which might affect two opposite arms of the bridge and thus doubled the deflection. Another switch might have been inserted in the other pair of arms and thus doubled the deflection again but errors due to the switches would also have been doubled and no advantage gained. The switch was carefully constructed with large copper rods dipping into copper mercury cups but, at best, the inaccuracies of the switch limited the accuracy of the experiment.

The fine adjustments were made by resistance boxes shunted round one of the coils. About 15,000 ohms in this shunt balanced the bridge. A change of one ohm in the shunt gave a deflection of two millimeters and indicated a change in the resistance of the arm of $\frac{5}{1000000}$ ohm. The whole resistance being over 100 ohms this would give a determination of one part in 2,000,000 or, since the deflection is doubled, one part in 4,000,000 for each arm. The result of 30 readings each way was that the shunt resistance was about 3.4 ohms less with magnetic field than without. The shunt was so placed that this gives a less resistance by one part in 1,200,000 when producing a magnetic field.

The above result is in the wrong direction. The difficulty may lie in the fact that the galvanometer, though used at night, was unsteady at best, or it may be due to leakage. The resistance of the coils was 100 ohms while the insulation resistance was 11,000,000 ohms. If the leakage is symmetrical along the doubled wire it will not affect the galvanometer upon reversing the current in one coil. This assumption may not be justified.

Apparatus and Plans for Operation at the Total Solar Eclipse, May 28th, 1900. By J. S. Ames.

The physical department of the Johns Hopkins University was invited by Professor S. J. Brown, astronomical director of the U. S. Naval Observatory at Washington, D. C., to co-operate with the Naval Observatory in preparations and observations, for the total eclipse on May 28. The path of totality was to extend from New Orleans to Norfolk, across all the intervening States; and arrangements were at once made to establish stations for observations at two points, one at the centre of the path, the other near the northern edge. The former was at Pinehurst, N. C.; the latter, Griffin, Georgia. At or near each of these places there was a station of the staff of the Naval Observatory.

The main features of interest to the physicist seemed to be the nature of the chromosphere and the corona; and for the purpose of studying these special apparatus was designed and constructed, largely under the direction of Mr. L. E. Jewell and Dr. N. E. Dorsey. Four spectroscopes were constructed, two for concave gratings, two for plane ones; and one of each was installed at each of the stations. The mounting of the plane-gratings was as follows: the light which would come from the heliostat would enter a light-tight box, fall upon the grating, and be diffracted so that the first spectrum focused by a quartz lens would be incident upon the photographic plate. The axis of the lens was so turned, and the photographic plate so bent that correction was made as far as possible for the spherical and chromatic aberration of the quartz lens. The box containing the apparatus was turned and supported at such an angle that the lines of the grating were parallel to the line of cusps at second contact. The gratings had 15,000 lines to the inch and a ruled surface 3 x 5 inches.

The concave-gratings were mounted as in the usual Rowland form; the slit, grating and centre of camera-box being held by steel tubing in their proper positions. The whole apparatus was enclosed in a light-tight box which was so tilted that the slit was parallel to the line of cusps at second contact. The light from the heliostat was focused on the slit by a quartz lens. The gratings were of about 10 feet radius, and had 15,000 lines to the inch.

The plan of operations with the instruments was designed to be as follows: With the plane grating spectroscopes it was arranged to take a series of exposures during totality, of various durations, so as to secure the spectra of different layers of the chromosphere and corona. For this purpose a sliding camera was constructed, which allowed five consecutive exposures. With the concave gratings a similar series of five exposures was arranged for. The slit was to be left wide open, and the different layers of the chromosphere were to be kept in the same position in the open slit by the aid of an eye-piece and focusing screws attached to the quartz lens. The eye-piece was provided with cross hairs, and was to be so placed as to have the F (hydrogen) line of the second spectrum in focus. When, owing to the gradual eclipsing of the layers of the chromosphere, the layer which is serving as the slit of light would be displaced sidewise, it could be brought back to the proper position by the slow motion of the quartz lens. At the middle of totality, the image on the slit could be shifted the necessary amount to bring the other edge of the sun under observation.

With all the grating spectroscopes adjustments were made so as to photograph as far as possible into the ultra-violet.

It was thought important to make further study of the polarization of the corona; and three different pieces of apparatus were constructed for this purpose. One was devised to take a series of photographs of the corona through a large double-image rhomb, which was placed in succession at different azimuths. The image of the sun was to be formed by a lens, 18 inches focus, thus having a diameter of one-fifth of an inch. In a second tube, fastened to the first, a similar plan was arranged with a direct-vision spectroscope of large dispersion, in order to see if by any chance the bright line spectrum of the corona was polarized. A pile of glass plates was also arranged in such a manner as to give some idea as to the intensity of polarization in any one layer around the sun, and also out along a radius.

An Alteration in the Undergraduate Courses in Physics. By J. S. Ames.

The present system of undergraduate instruction in Physics at Johns Hopkins University includes work for two years, so-called Minor and Major Courses. Each consists of four hours a week class-work, three hours lectures and one hour recitation; there is also laboratory instruction in connection with each course, from three to six hours weekly. The minor course is a general one, and treats the whole range of Physics in an elementary manner; the major course is largely mathematical, being the application of the methods of the calculus to physical phenomena. It has been found that this latter course is rather difficult for undergraduate students; and it is proposed to substitute for it in following years a course which will be largely descriptive, with only such mathematical discussion as is absolutely essential for a proper understanding of the subject. Special attention will be given modern developments in various fields of Physics, and there will be many illustrative experiments performed in the class-room. Full description will be given also of the general classical experiments on which our exact knowledge of Physics is based. In this way it is hoped to make the course both more interesting and more profitable to the undergraduate students and also to such graduate students as do not possess the necessary information.

There will be also a course on elementary Mathematical Physics for the graduate students in Physics, which will introduce the student to the more advanced and theoretical portions of the subject. This course will be a systematic one, extending through three years, and will embrace such subjects as mechanics, hydrodynamics, thermodynamics, electric oscillations, physical optics, spherical and Bessel functions, general mathematical theorems, the theory of the potential, etc.

Another course of instruction, consisting of laboratory instruction and demonstrations, has been arranged for medical students, and will probably be offered this coming scholastic year.

Refraction of Short Wave Trains. By N. E. Dorsey.

In considering the refraction of light a question at once arises as to whether the medium requires time to settle down to a steady state. If it does, a short train of waves will be refracted differently from a long one of the same wave-length. As there were no data bearing on the subject, Professor H. A. Rowland requested me to investigate it. As outlined by Professor Rowland and carried out by Mr. A. W. Ewell and myself, the experiment was as follows:

A small Grubb prism spectroscope with four 60° inch prisms and two half prisms, with a reflecting prism at the end, so that it had an effective train of ten 60° prisms, was adjusted so that its eye-piece was near that of a plane grating spectroscope giving about the same dispersion in the green. At the intersection of the prolongations of the two collimators was placed an arc lamp fed with a magnesium salt, and the spectroscopes were adjusted until the "little b" group appeared as nearly as possible the same in both. Then the arc was replaced by a very quick spark between magnesium terminals and the lines were again examined in both instruments.

Since any train of light waves we can deal with is very long in comparison with the wave length of light, the effect looked for will make itself evident only by a modification of the appearance of the lines. In fact we shall have, superimposed on the ordinary line, the line due to the initial disturbance. This should cause the line to broaden or to appear hazy on one or both edges. In order to notice an effect of this kind a comparison line is necessary and for this reason the grating spectroscope was set up, so that we could observe in quick succession the ordinary line as given by the grating, and the one given by the prism spectroscope.

Owing to the faintness of the spectrum given by the prism instrument the results are entirely negative in character, but there was not the slightest indication of any change in the appearance of the lines. In our case indeed I think there was really no change; for although the entire duration of the light of the spark was not more than 10^{-6} or 10^{-7} seconds this is a very long time as compared with the period of light waves. As stated above, it was not possible to use a quicker spark owing to the faintness of the spectrum.

The intensity of the spectrum furnished by the prism instrument was so much less than that from the grating, that it seemed advisable to make a rough comparison of the efficiencies of the two instruments. By the efficiency of a spectroscope I mean the ratio of the product of the intensity of spectrum times its width to the total amount of light falling on the first prism or grating, as the case may be. As the average of several observations I found that the grating spectroscope (a very ordinary grating was used) was 3.5 times as efficient in the red, 4.6 in the yellow, 5.9 in the green, and 7.9 in the blue, as the Grubb spectroscope. I used the spectrum of the first order.

Notes on the Zeeman Effect. By H. M. Reese.

Preliminary notes of this investigation, were published in these *Circulars* in June, 1898, and June, 1899.

During the present year the spectra of magnesium, cadmium, zinc, mercury, carbon, iron and titanium have been investigated. For this work a large new magnet was constructed with pole-pieces 1½ inches in diameter, which gave a very uniform field of 26580 C. G. S. units under working conditions. The other apparatus is substantially the same as that formerly used, and reference may be made to the former publications for description.

The lines 4678.37, 4800.09, 5086.06 of cadmium, 4680.38, 4727.26, 4810.71 of zinc, and 5167.55, 5172.87, 5183.84 of magnesium, were used to determine the variation of the separation with the magnetic field. A series of photographic plates were taken of the cadmium and zinc lines, using a spark between cadmium and zinc terminals, with the field varying from 6125 to 26580 C. G. S. units. A similar series was taken giving the magnesium lines and the cadmium line at 5086.06. After the separation was measured on all the plates a curve was plotted for each line, having magnetic forces as abscissae and separations as ordinates. For the lines 4678.37 4680.38, 5167.55, which are sharp triplets, the curves are straight lines with an indication of a possible drooping toward the axis of abscissae at more intense fields. The curves for the lines 4800.09, 4722.26, 5172.87, all sextuplets, show a more decided tendency to droop at high fields, and in those for 5086.06, 4810.71, 5183.84, diffuse triplets, this tendency is very marked, although in all cases the lower part of the curve is perfectly straight. It seems then that for many lines the separation is proportional to the strength of the magnetic field only for rather weak fields.

A few plates were taken of the spark between carbon terminals. The carbon band at about 3800 shows not the slightest indication of magnetic effect for a field of 25000 units, but these plates are mainly useful for the impurities that were in the carbon, and whose spectra appear on the plates. Many iron lines appear, and are all well-defined and in most cases well separated. This is really a very good means of getting the iron spectrum in measurable fields for iron terminals greatly change the distribution of the lines of force. The silicon line 3905 also appears with a separation of .209 Å.U. between its lateral components for a field of 25000 units. For the same field the aluminium line at wave-length 3961 and the calcium line at wave-length 3933 appear as triplets with separations .24, and .22 respectively; while the aluminium line at 3944 and the calcium line at 3968 are quadruplets. For the former the separation of the outer components is .28 Å. U., that of the inner ones .14, while for the latter that of the outer components is .28, of the inner .145.

On a plate taken with titanium, three lines appear, at wave-length 3658.3, 3759.4, 3761.4. In a field of 25000 units, all these are clear, well-defined triplets, with separations of .27, .31, and .35 Å. U. respectively.

Recently the question of the symmetry of the magnetic group has been brought forward by Voigt, whose theory indicates that for weak fields it should be asymmetrical as regards both intensity and location. Zeeman has verified this for several lines. Besides the iron line at wave-length 3466 which, as reported in this *Circular* last year, appears to be asymmetrical as regards spacing, several other lines have been observed here which show the same peculiarity. For weak fields the "sharp triplets," already spoken of in the cadmium and zinc spectra, have the violet component farther removed from the central than the red component, but less intense. In the case of the sextuplets, which appear as quadruplets in weak fields, the mean of the inner component is farther to the violet than that of the outer; and the outer line on the red side is more intense than that on the violet side. For the diffuse triplets no measurements of the lateral separation were taken, but the red component is the more intense. All these lines become more symmetrical in all respects as the field increases.

I was assisted in this research by Mr. N. A. Kent, who will continue the work next year.

Note on the Conductivity of Solution of the Alkali Metals on Methyl Amine. By C. A. Kraus.

In studying the properties of solution of the alkali metals in liquid ammonia the conductivity of a lithium solution in methyl amine was tested in hope of its proving a good substitute for the metal-ammonia solutions. This solution was studied by Moisson.[1] It was found, however, that while the solution conducts, the conductivity is so low that it is of no value in the study of the conductivity of the metal solution. While according to Moisson, sodium and potassium are quite insoluble in methyl amine it was found that these metals dissolved very slowly and sparingly in the sample of liquid used. The liquid was purified by distilling from the lithium solution. This removes moisture and it is also highly probable, in view of the reaction between the alkali metals and ammonia, that the ammonia would also be removed. The solutions are blue, as are the other metallic-solutions, but so weak that one can see through a saturated solution one-half centimeter thickness. Potassium is much more soluble than sodium. Both metals react with the solvent, although slowly, the blue color disappearing at ordinary temperature only after five or six hours. A tube containing about a fourth of a grain of potassium in 1 cc. of methyl amine was heated to 100° C. After about eight hours the metal had all reacted with the solvent, leaving a yellowish-colored solution with excess of crystals of the reaction product in the bottom of the tube. On cooling, more crystals were deposited. Hydrogen was given off during the reaction and was found on opening the tube. The crystalline compound is probably a substituted methyl amine formed according to the reaction—

$$CH_3NH_2 + K = CH_3NHK + H.$$

This compound reacts violently with water, the gases igniting. It is certain that the methyl amine contained insufficient ammonia to enable the formation of potassamide.

The solution of sodium and potassium also conducted, but also to a small extent compared with the ammonia solutions. There was some polarization, but it was very small, and is easily explained by the presence of the amide which is constantly being formed.

It may also be noted that sulphur in methyl amine conducts the current, but with marked polarization and with decomposition of the solution. The products of this decomposition have not been studied.

The Spectra of Mercury. By W. B. Huff.

In 1894 Eder and Valenta announced their discovery of the band-spectrum of mercury in vacuum tubes and that by the use of capacity in the secondary of the induction coil, this band-spectrum could be broken up into one consisting of a very large number of lines.

The object of the present investigation was to make a detailed study of the spectra of mercury in tubes, with particular reference to transition spectra obtained by varying the conditions of the discharge through the tube at various temperatures and pressures.

Preliminary to the work with tubes, the arc-spectrum was obtained, substantially as given by Kayser and Runge, with the addition of some lines in the extreme ultra-violet.

The spectrum of the spark in air was studied with the large concave grating of 21 feet radius. The discharge was from a large induction coil whose primary carried an alternating current. With no capacity in the secondary, the discharge from this coil gave the spectrum of the arc. With capacity the characteristic spark lines were brought out. With a large capacity, the lines become very hazy and there was much continuous spectrum. Other conditions being the same, a long spark gave lines not found in the spectrum of a short one.

Self-induction with capacity in the secondary cut out the air lines and some lines peculiar to the spark. The continuous spectrum disappeared and the lines came out more sharply.

When the discharge from an ordinary induction coil was passed through a vacuum tube with mercury electrodes, the light directly from the surface of the mercury gave the bands.

Heating the tube strongly caused the bands to disappear. With mercury distilling through the capillary, the introduction of capacity in the secondary brought out the line spectrum. The number of lines in this spectrum increased with increase of capacity. Self-induction cut out many of the lines of this spectrum and, as in the case of the spark in air, tended to reduce the spectrum to that of the arc.

As the pressure in the tube was decreased, the capacity necessary to break up the bands became less and the resulting lines were sharper. The relative intensities in this spectrum were very different from those in tubes sealed off at higher pressures, but when heated, a low-pressure tube gave substantially the same lines as were found in the spectrum of one containing a larger amount of air. In the spectrum of low-pressure tubes heated only by the discharge, several groups of lines were found which could be identified directly with groups of air lines on plates of the spark in air. When the tube was heated until the mercury distilled freely through the capillary, these air-lines could no longer be traced on the plates.

Plates showing the entire tube were also obtained by means of a plane grating used as objective. When the tube was cool, bands were seen through the entire length of the discharge. Heating the tube slightly and using capacity, the bands were broken up into lines in the capillary only. With strong heat, the bands disappeared wholly and much continuous spectrum came out at the electrodes.

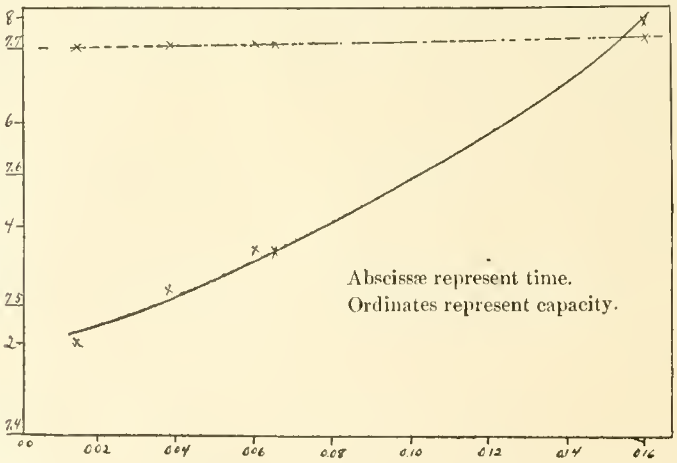
An examination of tubes with external electrodes showed bands throughout the tube, and very strongly on each side of a globule of mercury in the capillary.

The results from using an ordinary induction coil were the same as those from using a strong alternating discharge.

Electric Absorption in Condensers. By L. M. Potts.

In the *University Circular* for June, 1899, there was a note on Electric Absorption in Condensers by the author. The work reported then has been continued and some additional results obtained.

The method there described for the measurement of the electric absorption as a resistance has been used in the present investigation. In the note referred to, the resistance due to the electric absorption in a condenser, made in a vacuum under pressure, was shown to vary directly as the period of the current, and was shown to be independent of the strength of the current. In addition to the results obtained then, the value of $\frac{A}{T}$, (*i. e.*, the value of the electric absorption in ohms at period T, divided by the period T) has been determined for various temperatures. The temperature was found by a thermometer thrust through a hole in the box enclosing the condenser. From this investigation it was found that, at



Abscissæ represent time.
Ordinates represent capacity.

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[1] *Comptes Rendus*, Vol. 128, p. 20, 1899.

ordinary laboratory temperatures, a change of 0.1° C. caused a change of nearly 1 per cent. in the value of $\frac{A}{T}$.

The electric absorption of two one-third microfarad condensers was also studied. The relation here between the electric absorption A and T was not the simple relation found in the case of the wax condenser. From $T = .09$ sec. to $T = .04$ sec. the value of A could be represented by a formula of the form $a\,T - b$. For T less than .04 sec. the curve is slightly concave upwards.

From the theory of electric absorption given in the June *Circular*, 1898, it appeared that the capacity should also show a variation with the period. For a test of this point the method used was one described in the *American Journal of Science* for December, 1897, by Prof. Rowland (method 3). The different sources of error were tested, namely, electrostatic action, and induction of different parts of the apparatus on one another. The corrections due to electric absorption and self-induction of the coils of the electro-dynamometer were also studied. After the apparatus had been arranged to as good advantage as possible, results were obtained which agreed to 3 parts in 1,000 for varying conditions. The curve given in the figure shows the relation between the period and the capacity. The curve is drawn on two scales, the broken line on a small scale and the full line on a larger scale to show the nature of the variation of the capacity with the period. The term in the capacity depending on T does not appear to vary far from being proportional to the first power of T.

The final results of the investigation verify the theory in as far as a condenser possessing electric absorption acts as a certain capacity in series with a resistance. The value of the capacity and resistance each being dependent on the period of the current. However, the nature of the variation does not agree with the theory.

Rowland's New Method for the Measurement of Hysteresis and Foucault Current Losses in Iron and the Detection of Short Circuits in Coils. By L. M. Potts.

In the *American Journal of Science*, December, 1897, Professor Rowland suggested a method for the measurement of hysteresis and Foucault current losses in iron. In the work reported below some tests of this method have been made.

The same arrangement is used as described in *American Journal of Science*, July, 1899, for the measurement of electric absorption. It merely consists of a Wheatstone bridge in one arm of which a large coil of wire and the fixed coils of an electro-dynamometer are connected in series. The hanging coil of the electro-dynamometer is in the cross connection of the bridge. The bridge is adjusted for no deflection as in the application to the determination of electric absorption. A few plates of transformer iron, in which the hysteresis and eddy current losses are desired, are fitted around the coil. The energy losses in the iron act, as in the case of electric absorption, as an added resistance in series with the coil. The current flowing through the coil was determined by passing a small part of it through an electro-dynamometer. From the value of the current i, the period of the current T, the volume of the iron v, the value of the resistance due to the losses in the iron H, we have that the energy loss per cycle, per cc. is

$$\frac{i^2 HT}{v}.$$

The value of the corresponding induction in the iron B was determined by measuring with an electro-dynamometer the electromotive force induced around a small coil encircling the iron. The values thus determined for different values of the induction B and T constantly gave a very nice curve, plotting the energy loss per cycle, per cc., and B per sq. cm. of cross section of iron; the values also agreed very well with the curves given for losses in transformer iron, as found by other methods.

For the detection of short circuits the arrangement is the same as the preceding. The bridge is balanced, the coil to be tested is placed on top the coil already in one arm of the bridge, and any short circuit in the coil is shown by a deflection of the electro-dynamometer. The method was tested by using for the coil on the bridge a large coil of 5.3 henries, and laying on top of it short circuited coils of wire wound with different sizes of wire. The method was found quite sensitive. It appeared that if a large coil is used in the bridge a short circuit of only one turn in a coil, made of quite fine wire, may be readily detected. The sensitiveness may be increased by a decrease in the period of the current, and also by filling the centre of the coil with iron.

Some Properties of the Electric Spark and Its Spectrum. By C. C. Schenck.

The following is a preliminary note, the investigation not yet being finished.

The object of the investigation is to study some of the properties of the electric spark and its spectrum, from photographs taken by means of a revolving mirror.

The spark was produced by a battery of six large leyden jars charged by an alternating current, frequency 133 complete periods per second. The current was stepped up from 110 to 750 volts and then put through a specially designed induction coil, which gave a potential of about 10,000 volts. The strength of current through the coil was regulated by a suitable resistance in the primary circuit, which was found to be necessary in order to produce a very noisy spark which should not heat up the electrodes to the melting point. It is well known that when the current is too large for a given capacity, the metal of the poles becomes hot and the spark becomes less noisy and changes in character. It may be mentioned that this arrangement gave about 266 sparks per second for a spark 6 mm. long, although they did not follow each other with absolute regularity, and the number per second could be reduced by about one half by using a longer spark. The period of oscillation of the battery, found by measuring the image of the spark on the photographic plate, was 1.3×10^{-6} seconds.

To photograph the spark, a narrow, vertical slit was placed as close to it as possible. The light from the slit fell upon a rotating mirror, and was reflected thence through the lens of a camera, and the image of the slit focussed on the ground glass. The mirror was driven by an air blast and rotated about a vertical axis. There was no attempt made to secure synchronism between the appearance of the spark and the position of the mirror, but each discharge was sufficiently brilliant to produce an impression upon the plate.

To photograph the spectrum, it was found, after several trials, that best results were gotten by placing the spark and slit off at a considerable diatance, 225 cm., from a single prism of flint glass. After refraction, the light struck the mirror and was reflected into the camera. The prism was carefully adjusted for minimum deviation for the magnesium line λ 4481. Two sets of photographs of the spectrum were taken. In the first series the axis of the mirror was horizontal, so as to draw out the lines of the spectrum in the direction of their length. In the second set it was vertical, so as to broaden out the lines in a direction perpendicular to their length.

When the spark alone is photographed by means of the rotating mirror, the effect of the oscillatory discharge is clearly shown, but the character of the first discharge is different from that of those that follow. The first discharge is shown on the plate by a straight, somewhat broad line of light, showing that the electricity, in passing across the spark gap, lights up its entire path with a brilliant illumination. The next discharge in the opposite direction may produce a similar weaker illumination; the succeeding oscillations, however, do not light up brilliantly their whole path, but produce curved lines of light which shoot out from the poles, and become constantly more inclined as they approach the center of the spark. This means that the luminosity advances from the pole toward the center of the spark with diminishing velocity. It was noticed that the luminosity always proceeds from a pole of the same nature. This has been shown by other observers. (Feddersen, *Pogg. Ann.* 116, 1862; Schuster, *Phil. Trans.*, 193, p. 209.) To determine whether it is the anode or the kathode, the condensers were charged by a Holtz machine, and their electrification carefully tested before the spark passed, by a gold-leaf electroscope. Magnesium poles were used and several plates taken. Each one showed clearly that in this case it is the kathode from which the luminosity advances. Whether the light is due to an actual streaming out of light-giving particles, or simply to an advancing wave of luminosity like that in a Geissler tube, is an open question.

When the spectrum is photographed with the axis of the mirror placed vertically, so as to spread out the lines of the spectrum in a direction perpendicular to their length, it is found that the air lines are slightly broadened, the amount of broadening depending upon the speed of the mirror. The magnesium line, λ 4481, presents the appearance of a broad, inclined stream of light, crossed by a regular succession of ten or more steeper lines, which correspond to the curved lines of light seen in the oscillations of the plain spark.

If we attempt to get the speed of the metallic vapor by measuring the slope of the lines, a difficulty appears at once. The slope of the edge of the line indicates approximately a speed of 5×10^{4}, while the slope of the steeper lines indicates approximately a velocity of 20×10^{4}. There may be two distinct velocities. It is possible, however, that the flatter line is a sort of envelope of the successive steeper ones.

When a narrow spectrum is photographed with the axis of rotation of the mirror horizontal, so that the lines of the spectrum are drawn out in the direction of their length, it affords a method of determining the duration of different lines. It was found that the duration of the continuous spectrum which occurs with a strong spark was so short that it could not be measured. The air lines are slightly prolonged. Their duration did not exceed 2.5×10^{-6} seconds. With the metallic lines the most striking peculiarity was that the duration of the principal lines common to the spectra of both arc and spark considerably exceeded that of lines peculiar to the spectrum of the spark. With magnesium, the triplet λ 3838.4, which occurs in the arc, lasted 45×10^{-6}. The line λ 4481, peculiar to the spark, lasted 24×10^{-6} seconds. With cadmium, the arc lines 4678.4 and 4800 lasted 36×10^{-6} seconds. The line 4416, extremely weak in the arc, lasted 18×10^{-6} seconds. With zinc, the arc lines 4722 and 4810.7 lasted 24×10^{-6} seconds. The lines 4912 and 4925, peculiar to the spark, lasted 14×10^{-5} seconds. It should be added that all these metallic lines were knotted as a result of the oscillations, but the beading was more distinct with the lines peculiar to the spectrum of the spark than with the arc lines.

Notes on Rotatory Polarization Produced by Torsion.

By Arthur W. Ewell.

The following are a few experiments in continuation of the work described in the *American Journal of Science* for last August and in abstract in the *Physikalische Zeitschrift* for the fourteenth of last February, where it was shown that torsion produces rotatory polarization which is along the axis of torsion, in the opposite direction to the torsion and which is a function of the twist of a degree higher than the first.

Glycerine was stirred in a glass vessel and twisted in rubber tubes with glass caps and examined for rotatory polarization while being twisted, but no indication of rotatory polarization appeared even when the glycerine was cooled below zero degree centigrade.

Next was examined the effect of twisting glass rods when hot and allowing them to cool under twist. Jena glass alone was sufficiently transparent and as no Jena glass rods could be obtained rods were made by caving in heavy glass tubing. To remove the double refraction from the strains introduced in this method of manufacture, the rods were subjected to prolonged heating at a red heat, then twisted and allowed to cool under twist. Here again there was no indication of rotatory polarization. One of these rods, 3 cm. long, which had received a relative twist at the two ends of nearly two revolutions, did not rotate the plane of polarization more than 5°. On account of irregularities in the field it was impossible to set a lower limit.

It has been questioned whether the phenomena are not closely limited to the axis of torsion. Although in the experiments of last year the rotation appeared quite uniform over the entire cross section, in order to more definitely settle the question the following experiments were made:

Twisting glass tubes was first tried, but no determinations could be made on account of poor transparency and double refraction. Therefore, recourse was had to the jelly tubes which had proven so satisfactory in the work referred to above. Calves-foot gelatine was reduced to a jelly by the application of water and gentle heat and poured through a slit in the side into a rubber tube, 6 cm. long and 1.5 cm. internal diameter, with glass plates cemented to the ends and allowed to cool. To exclude rays near the axis of torsion, the central portion of the glass cap at each end was covered with a disk of black paper 5 mm. in diameter. The jelly gave a natural rotation of 5°. When the two ends were given a relative twist of about 60° and held fixed in clamps there was a superimposed rotation of the plane of polarization of about 6° in the opposite direction to the twist, and when the twist was about 135° the rotation was about 33°. The rotation varied slightly in different azimuths relative to the initial plane of polarization, but was very uniform over the annular cross section of the cylinder to which the rays were confined. On removing the paper disks the rotation at the centre was found to be practically the same as that outside.

To test the question still further, a cylindrical tube was made by cementing to glass plates one rubber tube within another, and filling the space between with melted jelly. The tubes were 4 cm. long and the internal diameter of the outer was 1.5 cm. and the external diameter of the inner .65 cm.

When the glass plates at the ends were given a relative twist of about 60° the plane of polarization was rotated 2° degrees in the opposite direction to the twist and 11° when the twist was 90°, the natural rotation of the jelly having been deducted. There was considerable double refraction which made the field of view somewhat irregular and the rotation somewhat variable in different azimuths.

The first mentioned tube was also tested in directions oblique to the axis by covering the ends with black paper except for two circular apertures, 3 mm. in diameter, diagonally opposite. The rotation was reduced as one would expect, being only about 11° for about 135° twist, but there was no appreciable double refraction.

Inductive E. M. F. in Transformers. By J. B. Whitehead, Jr.

[Abstract of paper in *Electrical World and Engineering*, May 5th, 1900.]

In the alternating current transformer the secondary E. M. F. at open circuit is that due to the induction in the core set up by the magnetizing current in the primary. When a load is put on the transformer both primary and secondary coils carry current and so each forms a considerable number of ampere turns or a magneto-motive-force; owing to the fact that the reluctance across the coil space is never so large as to allow it to be neglected, these two m. m. fs. set up fields of force, the lines of which in general only thread the particular coil inducing them; thus each of these "leakage" fields is a separate source of self-induction in its own coil, setting up in that coil a counter E. M. F. The effect of these E. M. Fs. on the regulation or "drop" in the transformer is evidently dependent on the phase differences between the E. M. Fs and currents, or more generally on the power factor of the load. The difficulty in estimating the regulation with a variation of the character of the load has been due to the fact that there are two separate E. M. Fs. of self induction to be taken into account.

The first object of this paper was to show from a study of the vector diagram of the transformer, that in their effect on regulation these two E. M. Fs. are practically in unison, and that if this sum or joint effect can be either measured or calculated, the diagrams and tables for estimating the drop in circuits containing only resistance and self induction may be used for figuring the regulation of transformers; the joint effect referred to is generally known as the "Inductive E. M. F." Next, a graphical proof is given showing that if the secondary be short circuited the E. M. F., which must be impressed on the primary in order to cause the full load current to flow, is the resultant of the ohmic and inductive E. M. Fs.; since these are always combined in the 90° relation this gives a means of measuring the inductive E. M. F.

In the latter half of the paper is developed a formula for calculating the inductive E. M. F. from the dimensions of the transformer; this formula is applied to several arrangements and sub-divisions of the coils in the same transformer and the following rule deduced:

If the secondary is in half as many parts as the primary and each part is between two primary parts, the inductive E. M. F. varies inversely as the square of the number of parts into which the primary is divided. If the primary and secondary are divided into the same number of parts and they are placed alternately, the inductive E. M. F. is decreased with increasing subdivision approximately, but not exactly, with the inverse square of the number of subdivisions of either coil.

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TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY.

An International Quarterly Journal

CONDUCTED BY

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WITH THE CO-OPERATION OF EMINENT MAGNETICIANS.

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PROCEEDINGS OF SOCIETIES.

Scientific Association.

Friday, March 9, 1900, *at* 8 *P. M.*—Special Meeting held in McCoy Hall.

A public address was delivered by Mr. FREDERICK E. IVES, of Philadelphia, on his "three colour system of Colour Photography."

March 22.—One hundred and fiftieth regular meeting.

The paper presented to the Association was "The Meaning of Science." by Prof. W. K. BROOKS.

April 26.—One hundred and fifty-first regular meeting. The President, Prof. REMSEN, in the chair.

Dr. W. S. THAYER reported on "Recent Investigations concerning the Aetiology of Malarial Fever."

Philological Association.

March 16, 1900.—One hundred and eighty-first regular meeting. Prof. BLOOMFIELD in the chair. Twenty-five members were present.

Papers read:

Secondary Accent in Anglo-Saxon, Determined by Metrical Criteria, by J. HUGUENIN.
Concatenation in the Rig-Veda, by J. A. NESS.

April 27.—One hundred and eighty-second regular meeting. Prof. GILDERSLEEVE in the chair. Thirty-four members were present.

Papers read:

Sources of Les Précieuses Ridicules, by J. D. BATCHELDER.
Milton's Conception of the Temptation as Portrayed in Paradise Regained, by R. D. MILLER.

May 18.—One hundred and eighty-third regular meeting. Prof. GILDERSLEEVE in the chair. Twenty-seven members were present.

Papers read:

The Auxiliary Use of Venire with the Past Participle in Italian, by J. E. SHAW.
Concerning Grammatical Ictus in English Verse, by J. W. BRIGHT.

Historical and Political Science Association.

March 16.—The Organization and Methods of the Twelfth Census, by W. F. WILLCOX.

March 16.—

Legal Status of Slaves in Virginia, by J. C. BALLAGH.
The Associate-Congregational Church in Baltimore, by J. M. VINCENT.
Giddings' Democracy and Empire, by R. J. MULFORD.
Baden-Powell's Village Communities in India, by V. E. SMITH.
W. Brown's New Democracy, by E. C. JOHNSON.
Ten Brink's Robespierre and the Red Terror, by B. KILBY.

April 6.—

Internal Improvements in North Carolina, by C. C. WEAVER.
Travels in Jamaica, by H. B. ADAMS.
Ely's Trusts and Monopolies, by G. CATOR.
Donaldson's Five Great Oxford Leaders, by J. W. HARRY.
Meigs' Growth of the Constitution, by H. S. HANNA.
Gorren's Anglo-Saxons and Others, by W. E. MARTIN.

April 20.—

The Life of Thomas Holliday Hicks, by G. L. RADCLIFFE.
Hart's S. S. Chase, by R. J. MULFORD.
Coubertin's France since 1814, by I. A. THORSON.
Ingram's History of Religion, by C. E. JOHNSON.
Adams' C. F. Adams, by V. E. SMITH.

May 11.—

Aboriginal Jamaica, by J. E. DUERDEN.
Australian Federation, by R. J. MULFORD.
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In Memoriam.

PROFESSOR THOMAS CRAIG.

THOMAS CRAIG, PH. D., Professor of Pure Mathematics in this University, died in Baltimore, May 8, 1900. Professor Craig was born in Pittston, Pa., in 1856. He was graduated from Lafayette College in 1875, and entered this University in 1876. He held a fellowship from 1876 to 1879, received the degree of Doctor of Philosophy in 1878, and has since held the positions of instructor, associate, associate professor, and professor here. He was for a brief period connected with the U. S. Coast Survey.

For many years he was associated with the *American Journal of Mathematics* as a contributor and as assistant editor, and from 1894 to 1899 he was the responsible editor of the journal.

At a meeting of the Board of University Studies, held May 23, 1900, the following minute was unanimously adopted:

"The members of the Board of University Studies of the Johns Hopkins University desire to express their sorrow at the death of their friend and colleague, Professor Thomas Craig, who, as student and teacher of mathematics, had been connected with the University for nearly the entire period of its existence. One of the brilliant young men whom Professor Sylvester attracted to the University in its early days, he won straightway the favorable notice of that eminent man for the enthusiasm and intellectual acumen with which he entered upon the study of advanced mathematics, then almost an unknown science in this country; and this fortunate combination of interest, energy, and ability characterized his entire career. At the time of his death he was occupied in the preparation of a treatise on the Theory of Surfaces. Undoubtedly the intense ardor with which he engaged in this work contributed in large measure to that impairment of the nervous system from which he had recently suffered. Professor Craig possessed great power of research, and wrote much for various mathematical journals. For many years he was editor of the *American Journal of Mathematics*, and it is largely due to his zeal and able direction that that Journal continues to hold its high rank in the mathematical world. Professor Craig occupied a place in the very front rank of American mathematicians. His scientific ideals were the highest, and as teacher, editor, and investigator, he brought to his work a high degree of originality, and an intellectual ardor which was a source of inspiration to all with whom he was closely associated."

CONTENTS.

PAGE.

NOTES FROM THE BIOLOGICAL LABORATORY:—

Observations on the Gametophyte and Embryo of Taxodium Distichum, Richard. By W. C. COKER, - - - - - - - - - - - - - - - 45
Plants, A Text-Book of Botany: A Review. By D. S. JOHNSON, - - - - 46
On the Embryo-sac of Saururus Cernuus. By D. S. JOHNSON, - - - - - 46
The Embryo-sac of Peperomia Pellucida. By D. S. JOHNSON, - - - - - 47
Order of Appearance of the Mesenteries and Septa in the Madreporaria. By J. E. DUERDEN, - - - - - - - - - - - - - - - 47
The Arterial Circulation of Nautilus Pompilius. By L. E. GRIFFIN, - - - 53
The Anatomy and Development of the Reproductive Organs of Planaria Maculata. By W. C. CURTIS, - - - - - - - - - - - - - 56

NOTES FROM THE PHYSICAL LABORATORY:—

Resistance to Ethereal Motion. By H. A. ROWLAND, N. E. GILBERT and P. C. MCJUNCKIN, - - - - - - - - - - - - - - - - 60
Apparatus and Plans for Operation at the Total Solar Eclipse, May 28th, 1900. By J. S. AMES, - - - - - - - - - - - - - - 60
An Alteration in the Undergraduate Course in Physics. By J. S. AMES, - - 61
Refraction of Short Wave Trains. By N. E. DORSEY, - - - - - - 61
Notes on the Zeeman Effect. By H. M. REESE, - - - - - - - - 61
Note on the Conductivity of Solution of the Alkali Metals on Methyl Amine. By C. A. KRAUS, - - - - - - - - - - - - - 62
The Spectra of Mercury. By W. B. HUFF, - - - - - - - - - 62
Electric Absorption in Condensers. By L. M. POTTS, - - - - - - - 62
Rowland's New Method for the Measurement of Hysteresis and Foucault Current Losses in Iron and the Detection of Short Circuits in Coils. By L. M. POTTS, - - - - - - - - - - - - - - 63
Some Properties of the Electie Spark and its Spectrum. By C. C. SCHENCK, - 63
Notes on Rotatory Polarization produced by Torsion. By ARTHUR W. EWELL, 64
Inductive E. M. F. in Transformers. By J. B. WHITEHEAD, JR., - - - 64

RECENT PUBLICATIONS IN PHYSICS, - - - - - - - - - - 65
PROCEEDINGS OF SOCIETIES, - - - - - - - - - - - 66
IN MEMORIAM:—PROFESSOR THOMAS CRAIG, - - - - - - - - 67

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